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FINAL

PHASE III RFI/RI ENVIRONMENTAL EVALUATION WORK PLAN

ROCKY FLATS PLANT

881 HILLSIDE
(Operable Unit No. 1)

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM

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ENVIRONMENTAL EVALUATION

6.1 INTRODUCTION

The objective of this Environmental Evaluation Work Plan is to provide a framework for addressing and quantifying the ecological effects to the biotic environment (plants, animals, and microorganisms) from exposure to contaminants resulting from IHSSs within the 881 Hillside site, Operable Unit Number 1, (OU1) of the Rocky Flats Plant. An ecosystem approach will be used as the basis for this environmental evaluation to ensure that ecological effects endpoints (e.g., structural diversity, biomass, phenology, nutrient cycling, trophic structure) are addressed as well as populations and individuals that are more traditionally evaluated in a risk assessment approach (U.S. EPA 1989a). The ecosystem approach is comprehensive in that it initially addresses all ecosystem components, then progressively focuses on those aspects of the system potentially affected by contamination. The result of this process will be an evaluation of the nature and extent of contamination in biota, its relationship to abiotic sources, and the type and extent of adverse effects at the ecosystem, population, and individual levels of organization, as appropriate.

This plan is prepared in conformance with the requirements of current applicable legislation, including the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and follows the guidance for such studies as provided in the National Contingency Plan (NCP) and Environmental Protection Agency (EPA) documents for the conduct of Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) activities. Specifically, the EPA guidance provided in Risk Assessment Guidance for Superfund, Vol. II, Environmental Evaluation Manual (U.S. EPA 1989b) is followed. Although a formal Natural Resource Damage Assessment (NRDA) process has not been initiated at Rocky Flats as of this time, this work plan was also designed to be consistent with the NRDA process to the maximum extent possible.

Determination of the effects on biota will be performed in conjunction with the human health risk assessment for OU1. Where appropriate, criteria necessary for performing the environmental evaluation will be developed in conjunction with human health risk assessments and environmental evaluations for all Rocky Flats Plant Operable Units (OUs). Information from the environmental evaluation will assist in determining the form, feasibility, and extent of remediation necessary for 881 Hillside in accordance with CERCLA.

During preparation of this work plan, several documents were reviewed as part of an assessment of available information. These included the Final Environmental Impact Statement (EIS), Rocky Flats Plant

(U.S. DOE 1980); Wetlands Assessment (EG&G 1990a); Draft Environmental Evaluation Work Plan for OU2 (in RFI/RI Work Plan, EG&G 1991a); and the Final Environmental Assessment for OU1 (U.S. DOE 1990a). Literature reviews will continue throughout the environmental evaluation. Review of the Phase III RFI/RI Work Plan for OU1 (EG&G 1990b) and the Environmental Evaluation Work Plans for OU5 (EG&G 1991b) and OU2 (EG&G 1991c) formed the basis for the establishment of the initial sampling locations presented in the OU1 Field Sampling Plan (Subsection 6.3).

6.1.1 Approach

This plan presents a comprehensive approach to conducting the environmental evaluation at 881 Hillside. This comprehensive approach is designed to ensure that all procedures to be performed are appropriate, necessary and sufficient to adequately characterize the nature and extent of environmental effects to biota under the "no action" scenario. The approach presented in this plan is adapted from the toxicity-based approach to the assessment of ecosystem effects (U.S.EPA 1989a, 1989b). The approach is based on standard risk assessment concepts whereby uncertainties concerning potential ecosystem effects are explicitly recognized and, where possible, quantified. The planned approach is also based, to the greatest extent possible, on providing objective estimates of ecological damage and the establishing a firm, causal relationship between contamination and ecological effects. To establish this relationship, the Work Plan focuses on the obtainment of three types of information:

- Chemical - Chemical analyses of appropriate media to establish the presence, concentrations, and variabilities of specific toxic compounds. This effort will be conducted under the RFI/RI abiotic sampling program.

- Ecological - Ecological surveys to characterize the condition of existing communities and establish whether any adverse effects have occurred.

- Toxicological - Toxicological and ecotoxicological testing to establish the link between adverse ecological effects and known contamination.

Without these three types of data, other potential causes of the observed effects on ecosystems unrelated to the presence of contamination, such as habitat alterations and natural variability, cannot be eliminated.

The ecological assessment scheme adopted for this project blends standard environmental and risk assessment methods with ecological and toxicological modelling to produce an integrated procedure for selecting contaminants of concern and indicator species, and for conducting an investigation of

ecosystem effects resulting from contamination. As is recommended by EPA, this environmental evaluation is not intended to be or to develop into a research-oriented project. The plan presented herein is designed to provide a focused investigation of potential contaminant effects on biota.

Each task of the environmental evaluation will be coordinated with RFI/RI activities at nearby operable units in order to avoid unnecessary duplication of effort and resources. Environmental evaluation planning is currently underway at two operable units in close proximity to OU1: OU5 (Woman Creek Drainage) and OU2 (903 Pad, Mound, and East Trenches Area). A coordinated approach with these operable units is necessary in order to account for contaminant migration into OU1.

The environmental evaluation process has been divided into ten tasks. These tasks and their interrelationships are shown on Figure 6-1. The following is a brief description of each of these tasks. More detailed descriptions of each task are presented in Subsection 6.2.

Task 1: Preliminary Planning

Task 1 will focus on planning and coordination of the OU1 environmental evaluation with nearby OU5 and OU2 activities. Task 1 will include a determination of the scope of work and a definition of the study area. The Data Quality Objective (DQO) process will be initiated in Task 1 according to EPA guidance (U.S. EPA 1987a or 1990), and procedures for monitoring and controlling data quality will be specified to the extent possible. Task 1 activities will include development of criteria for selection of contaminants of concern, key receptor species, and reference areas.

Task 2: Data Collection/Evaluation and Conceptual Model Development

Task 2 will include a review, evaluation, and summary of available chemical and ecological data and identification of data gaps. Based on these data, contaminants of concern will be identified based on their documented effects on key receptor species and/or other ecological endpoints. As part of the conceptual biota model development, a food web model will be constructed and preliminary exposure pathways will be identified. Results of these activities will be used to refine the ecological (Task 3) and ecotoxicological (Task 9) field investigation sampling designs.

Task 3: Ecological Field Investigation

Task 3 will include the preliminary field surveys, and an ecological field inventory to characterize OU1 biota and their trophic relationships and to note locations of obvious zones of chemical contamination. Brief field surveys will be conducted in the spring, summer, fall, and winter to obtain information on the

occurrence, distribution, variability, and general abundance of key plant and animal species. Field inventories will be conducted in late spring and summer to obtain quantitative data on community composition in terrestrial and aquatic habitats. Samples collected as part of the activity will be saved for tissue analyses where contaminants of concern have been identified and sampling protocol are in place. Task 3 will also include aquatic toxicity tests using Ceriodaphnia spp and fathead minnows. As part of these activities, all collected field data will be reduced, evaluated, compared with, and integrated into the existing database to update knowledge of site conditions.

Task 4: Toxicity Assessment

Task 4 will entail compilation of toxicity literature and the toxicological assessment of potential adverse effects from contaminants of concern on key receptor species. This task will be performed in conjunction with the following Task 5.

Task 5: Exposure Assessment and Pathways Model

Task 5 will entail development of a site-specific pathways model based on the ecological field surveys. This exposure-receptor pathways model will be used to evaluate the transport of contaminants at OU1 to biological receptors. The pathways model is based on a conceptual pathways approach (Fordham and Reagan 1991) and will provide an initial determination of the movement and distribution of contaminants, likely interactions among ecosystem components, and expected ecological effects. It is anticipated that this approach will be coordinated with the efforts of investigators working in other operable units to avoid duplication of effort, to collect comparable data, and to provide a consistent assessment of contaminant effects.

Task 6: Preliminary Contamination Characterization

Task 6 will provide a characterization of the threat or risk of OU1 contaminants to receptor populations and habitats. Determinations will be made as to the magnitude of the effects of contamination on OU1 biota. The actual or potential effects of contamination on ecological endpoints (e.g., species diversity, food web structure, productivity) will also be addressed. Depending on DQOs and the quality of data collected, the contamination characterization will be expressed qualitatively, quantitatively, or a combination of the two. Task 6 may include the preliminary derivation of remediation criteria. Development of these criteria will entail consideration of federal and Colorado laws and regulations pertaining to preservation and protection of natural resources that are Applicable or Relevant and Appropriate Requirements (ARARs). Information from ARARs, toxicological assessments, and the pathways model will be used to develop criteria that address biological resource protection.

Task 7: Uncertainty Analysis

Task 7 includes the identification of assumptions and the evaluation of uncertainty in the environmental risk assessment analysis. Task 7 will include the identification of data needs to calibrate/validate the pathways model developed in Task 5.

Task 8: Planning

Task 8 will entail the development of additional DQOs with respect to the conduct of Task 9, Ecotoxicological Field Investigation. DQOs to be achieved by such sampling will be defined according to EPA guidance (U.S. EPA 1987a or 1990). Scoping and design of Task 9 field studies will be based initially on the outcome of Tasks 1 through 3. Field sampling will only be performed where acceptance criteria for demonstrating injury to a biological resource will be satisfied in accordance with regulations under the Natural Resource Damage Assessment Rule [40 CFR Subtitle A Section 11.62 (f)] and the accompanying Type B Technical Information Document (U.S. DOI 1987).

Task 9: Ecotoxicological Field Investigation

Task 9 will include tissue analysis studies and any additional ecotoxicological field investigations. Samples collected in Task 3 field studies will be used wherever possible (e.g., when contaminants of concern have been identified and sampling protocols are in place); new samples will be collected if necessary. The need for measuring additional population endpoints through reproductive success, enzyme inhibition, microbial respiration, or other ecotoxicological studies will be evaluated based on the Task 3 preliminary ecological risk assessment. Selection of the target analytes, species, and tissues will be based on the determination of which contaminants are likely to be present in sufficient concentrations, quantities, and locations as to be detected in biota. Selection of these specific criteria will be developed in consultation with EPA and the State. All necessary federal and state permits will be obtained prior to any destructive sampling or collecting.

Task 10: Environmental Evaluation Report

Task 10 will provide a final characterization of contamination in biota at OU1. Results from the Task 9 ecotoxicological field investigations will be used to evaluate ecosystem effects. Information on site environmental characteristics and contaminants, characterization of effects, remediation criteria, conclusions, uncertainty analysis, and limitations of the assessment will be summarized into the Environmental Evaluation Report.

Each of the preceding tasks is described in further detail in Subsection 6.2. A suggested outline for the Environmental Evaluation Report is presented in Subsection 6.2.11. The field sampling plan presented

in Subsection 6.3 addresses both the Task 3 ecological investigation and the Task 9 ecotoxicological field investigations. A tentative outline for the environmental evaluation report is presented in Subsection 6.2.11.

6.1.2 OU1 Contamination

A number of chemicals are suspected to be present in OU1 soils and surface water at levels above background, as described in Section 2.0 of the Phase III OU1 RFI/RI Work Plan (EG&G 1990b). To determine above-background chemical levels, a comparison was made between the site-specific data and background data as presented in the Draft Background Geochemical Characterization Report (Rockwell 1989). A background tolerance interval for each analyte of concern was calculated (the maximum concentration detected was used in those cases where no tolerance level could be calculated). A summary of contaminants that were detected above background at any time during sampling, based on the information presented in Section 2.0, is shown in Table 6-1. Most of the contaminants are likely to impact biota if present at sufficient concentrations. The following subsections present a discussion of which of these chemicals are likely to be of paramount concern at OU1, given their toxic nature. Actual selection of contaminants of concern to biota will take place in Task 2 after a more detailed analysis of potential adverse effects and review of available toxicological literature. Further comparisons of site data to the more recent Geochemical Characterization Report (EG&G 1990c) to determine above background levels will also be made as part of the RFI/RI investigation.

6.1.2.1 Metals

Terrestrial Ecosystems

Heavy metals are the most commonly evaluated environmental contaminants in biomonitoring studies of terrestrial ecosystems. Studies on heavy metals are of several types: (1) reports of metal concentrations in animals from only one location, (2) correlations of tissue concentrations with environmental concentrations, (3) monitoring a site through time, (4) concentrations in animals collected along a gradient of pollution, and (5) comparisons of concentrations in animals from reference and contaminated sites or sites where contamination is suspected. These studies generally provide information on background concentrations of contaminants and correlations of tissue concentrations with environmental concentrations. Data from the Talmage and Walton (1990) study is available for most heavy metals for a variety of mammal species and lower trophic levels. Data from Talmage and Walton (1990) and other available studies on heavy metals effects on biota will be reviewed as part of the Task 2 effort and compared to OU1 data as appropriate.

TABLE 6-1

CHEMICALS DETECTED AT OU1 AT LEVELS ABOVE BACKGROUND

WOMAN CREEK DRAINAGE

Surface Water:

Organics:	methylene chloride, acetone, toluene
Metals:	zinc, strontium
Radionuclides:	uranium, plutonium, strontium-89 and -90, americium, cesium-137, and tritium

Sediments:

Organics:	no data available
Metals:	mercury and molybdenum
Radionuclides:	no data available

SOUTH INTERCEPTOR DITCH

Surface Water:

Organics:	tetrachloroethene, toluene, carbon tetrachloride, trichloroethene
Metals:	aluminum, beryllium, cadmium, copper, mercury, lead, selenium, zinc, chromium, barium, nickel, strontium
Radionuclides:	uranium, plutonium, strontium-89 and -90, americium, cesium-137, and tritium

Sediments:

Organics:	tetrachloroethene, chloroform, chloromethane, acetone, methylene chloride
Metals:	beryllium, silver, tin, aluminum, lead, cadmium, chromium, copper, lithium, magnesium, manganese, mercury, selenium, strontium, thallium, vanadium, and zinc
Radionuclides:	plutonium, uranium, and radium-226

Source: Section 2.0, Phase III RFI/RI Work Plan for OU1 (EG&G 1990b)

Several of the heavy metals detected at OU1 are phytotoxic and are known to bioaccumulate and biomagnify in terrestrial and aquatic ecosystems. Bioaccumulation, the process by which chemicals are taken up by organisms directly or through consumption of food containing the chemicals, is documented for arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, and selenium. Biomagnification, or the process by which tissue concentrations of chemicals increase as the chemical passes up through two or more trophic levels, is documented from soil to plants for beryllium, cadmium, chromium, copper, lead, mercury, and selenium. In herbivores, biomagnification occurs for antimony, arsenic, cadmium, chromium, copper, lead, mercury and selenium. In terrestrial carnivores, mercury and cadmium are known to biomagnify. Any, if not all, of these metals are likely to become contaminants of concern in the OU1 environmental evaluation, depending on historical usage, concentrations detected in soils, and uptake by biological receptors at OU1.

While numerous studies have been conducted with respect to metals effects on biota, there are no readily available criteria for providing an initial rapid assessment of contaminants most likely to be of concern in terrestrial ecosystems. Health-based "environmental action criteria" are available in the RCRA Facility Investigation (RFI) Guidance Document (U.S.EPA 1989c) for carcinogens and noncarcinogens in the soils ingestion pathway for humans. These criteria were compared to the maximum contaminant levels for metals in soils and sediments at OU1 to provide an initial assessment of the likely contaminants of concern (Table 6-2). A safety factor of 100 was applied to these criteria, based on the assumption that biota are 100 times more sensitive than humans. It should be noted that only a few of these criteria used are suitable for comparison purposes, as most of the criteria are for metals complexes, whereas concentrations reported for OUI are for total metals.

Based on this initial comparison of maximum levels detected for metals to the environmental action criteria, beryllium and cyanide are metals whose potential toxic effects should be closely examined with respect to onsite contaminant levels and potential adverse effects on biota. Contaminants such as mercury, cadmium, and lead, for which no environmental criteria are available, will require in-depth evaluations given their considerable potential to biomagnify. It should also be noted that the maximum concentrations reported for alluvium soil in Table 6-2 are from composited samples. Maximum concentrations in uncomposited surficial soils, which are of the greatest concern from an environmental risk perspective, may be considerably higher.

Aquatic Ecosystems

EPA has established ambient water quality criteria (AWQC) to be protective of the environment (U.S. EPA 1986). Specifically, these criteria represent the maximum allowable water concentrations consistent with the protection of aquatic life. One rationale for establishing criteria protective of aquatic life is that

TABLE 6-2

COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES FOR METALS TO ENVIRONMENTAL ACTION CRITERIA

Parameter	Soil & Sediment Environmental Action Criteria[1] (mg/kg)	Sediment Concentration[(a)] (mg/kg) (Sample #)	Soil	
			Rocky Flats Alluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]	Colluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]
TOTAL METALS				
Aluminum	30[2]	24,800 (SD030)	17,100 (BH6387) 0.00-8.00	21,200 (BH0387) 2.45-3.90
Antimony	30	24.5 (SD025)	--	24.0 (BH0487) 0.00-10.00
Arsenic	---	7.2 (SD001)	13.4 (BH6387) 0.00-8.00	24.0 (BH0487) 0.00-10.001
Barium	4,000	300 (SD030)	165.0 (BH6387) 0.00-8.00	811 (BH1387) 0.00-10.00
Beryllium	.143	15.5 (SD028)	1.1 (BH6387) 0.00-8.00	1.20 (BH1487) 2.00-2.90
Cadmium	---	2.3 (SD029)	3.5 (BH1587) 0.00-5.00	6.40 (BH1487) 2.00-2.90
Chromium	III - 80,000 VI - 400	26.8 (SD030)	24.2 (BH6387) 0.00-8.00	27.8 (BH1487) 2.00-2.90

TABLE 6-2
COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES FOR METALS TO ENVIRONMENTAL ACTION CRITERIA
(Continued)

Parameter	Soil & Sediment Environmental Action Criteria[1] (mg/kg)	Sediment Concentration[(a)] (mg/kg) (Sample #)	Soil	
			Rocky Flats Alluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]	Colluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]
Cobalt	---	9.5 (SD014)	---	12.8 (BH5887) 0.00-1.70
Copper	400[3]	40.4 (SD029)	17.5 (BH6387) 0.00-8.00	23.2 (BH0987) 10.08-11.30
Cyanide	2,000	---	4850 (BH6387) 0.00-8.00	6800 (BH5987) 2.00-3.50
Iron	---	28,900 (SD030)	21,300 (BH6387) 0.00-8.00	22,800 (BH0387) 2.45-3.90
Lead	---	66.4 (SD030)	14.2 BH6387 0.00-8.00	24.0 (BH1187) 0.00-10.00
Lithium	---	13.2 (SD029)	---	18.4 (BH1487) 2.00-2.90
Magnesium	---	5,970 (SD030)	5,720 (BH6387) 0.00-8.00	6,330 (BH0387) 2.45-3.90

TABLE 6-2
COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES FOR METALS TO ENVIRONMENTAL ACTION CRITERIA
(Continued)

Parameter	Soil & Sediment Environmental Action Criteria[1] (mg/kg)	Sediment Concentration[(a)] (mg/kg) (Sample #)	Soil	
			Rocky Flats Alluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]	Colluvium Concentration[(b)] (mg/kg) (Sample #) [Depth - Increment(ft.)]
Manganese	---	1,390 (SD030)	185 (BH6387) 0.00-8.00	563.0 (BH0687) 2.00-2.90
Mercury	---	0.56 (SD030)	0.60 (BH1587) 0.00-5.00	2.07 (BH0687) 2.00-2.90
Molybdenum	---	42.0 (SD014)	---	---
Nickel	2,000	24.6 (SD026)	20.2 (BH6387) 0.00-8.00	24.8 (BH1487) 2.00-2.90
Potassium	4,000[4]	67,000 (SD002)	1,490 (BH6387) 0.00-8.00	3,040 (BH0387) 2.45-3.90
Selenium	---	21.3 (SD030)	---	---
Silver	200	49.1 (SD030)	---	---
Strontium	---	179 (SD030)	63.5 (BH6387) 0.00-8.00	209 (BH6187) 6.50-9.001

TABLE 6-2
COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES FOR METALS TO ENVIRONMENTAL ACTION CRITERIA
(Concluded)

Parameter	Soil & Sediment Environmental Action Criteria[1] (mg/kg)	Sediment Concentration[a] (mg/kg) (Sample #)	Soil	
			Rocky Flats Alluvium Concentration[b] (mg/kg) (Sample #) [Depth - Increment(ft.)]	Colluvium Concentration[b] (mg/kg) (Sample #) [Depth - Increment(ft.)]
Thallium	20-40[5]	13.0 (SD002)	---	---
Tin	---	1,080 (SD030)	---	---
Vanadium	2,000[6]	58.4 (SD030)	25.6 (BH6387) 0.00-8.00	51.6 (BH5787) 10.00-12.00
Zinc	20-4,000[7]	140.0 (SD029)	66 (BH1587) 0.00-5.00	77.2 (BH5787) 10.00-12.00

Explanation of Table:

1 Risk criteria are the lowest concentrations reported for Health-Based Criteria for Systematic Toxicants and Carcinogen. (Tables 8-6 and 8-7 in EPA 1989c). Criteria reported in Tables 8-6 and 8-7 are reduced by 100 to provide a safety factor to biota.
2 Criteria for aluminum phosphide.
3 Criteria for copper cyanide.
4 Criteria for potassium cyanide.
5 Criteria range for thallium compounds.
6 Criteria for vanadium pentoxide.
7 Criteria range for zinc cyanide and zinc phosphide.
(a) Values reported in Appendix D of the Final Phase III RFI/RI Work Plan for OU1 (EG&G 1990b); values reported as either 1) analyzed but not detetected or 2) rejected, were not considered.
(b) Values reported in Appendix A of the Final Phase III RFI/RI Work Plan for OU1 (EG&G 1990b); values reported as either 1) analyzed but not detetected or 2) rejected, were not considered.

aquatic organisms and plants are important in food chains to higher life forms. In addition, their direct dependence on the aquatic environment results in constant contact with the water and the organisms are therefore likely to assimilate any contaminants. One EPA objective in establishing AWQC was to determine chemical concentrations that would not be directly harmful to aquatic organisms and plants and would not present a hazard to higher life forms due to any biomagnification of individual chemical substances.

Of the maximum levels of metals detected in surface water at OU1, thirteen are of immediate interest in the evaluation of aquatic ecosystems given their presence at levels above federal surface water quality standards (Table 6-3). These are aluminum, barium, beryllium, chromium, copper, cyanide, iron, lead, manganese, mercury, selenium, silver, and zinc. Of these metals, chromium, copper, lead, mercury, selenium, and zinc are likely to be contaminants of concern because of their potential to biomagnify. Cyanide, which doesn't necessarily biomagnify, is likely to be a contaminant of immediate concern given its detection at an elevated level and its ability to have direct toxic effects on aquatic organisms. Brief summaries of information from the AWQC document (U.S. EPA 1986) and other available toxicological literature on these metals of likely concern are presented in the following text. Similar toxicity profiles will be evaluated against site-specific concentrations data in the selection of contaminants of concern and key receptor species. The occurrence of these metals at elevated levels does not necessarily imply that they are available for assimilation in all organisms or that they transfer to successive trophic levels. The potential for adverse effects to occur is dependent of a number of physicochemical factors including: (1) physiological and ecological characteristics of the organism; (2) forms of dissolved trace metals; (3) forms of trace metals in ingested solids; and (4) chemical and physical characteristics of water (Jenne and Luoma 1977). Each of these factors will be considered in the evaluation of potential adverse environmental effects at OU1.

Aluminum

No aquatic life criteria have been set, although EPA has proposed a Maximum Contaminant Level (MCL) of 50 ug/l. EPA has suggested ambient concentration limits for the protection of human health: 73 ug/l for aluminum and aluminum compounds, and 138 ug/l for aluminum oxide. The 28-day LC50 (the chemical concentration in water to which test organisms are exposed that is estimated to be lethal to 50 percent of the test organisms) value for aluminum chloride using rainbow trout (Oncorhynchus mykiss) is reported at 560 ug/l and the 48-hour LC50 value for sodium aluminum silicate using water flea (Daphnia magna) is reported to range from 1,000 mg/l to 1,800 mg/l.

TABLE 6-3

COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR METALS TO FEDERAL AND STATE WATER QUALITY STANDARDS (μg/l)

Parameter	Maximum Value Reported[a]	Location	FEDERAL STANDARDS			STATE STANDARDS			
			AWQC for Protection of Aquatic Life[b]			Biological Parameters for Aquatic Life[d]		Stream Segment Standard[e]	
			Acute	Chronic	MCL[c]	Acute	Chronic	Acute	Chronic
Aluminum	57600	SW-67			50[1]	950	150		
Antimony	64	SW-66	9000[2]	1600[2]					
Arsenic[4]	9.1	SW-70	360-III 850-V	190-III 48-V	50			50	
Barium	1100	SW-44			1000				
Beryllium	17.3	SW-67	130[2]	5.3[2]					
Cadmium	6.8	SW-33	3.9[5]	1.1	10	TVS	TVS	TVS	TVS
Cesium	2500	SW-44,45,46							
Chromium[4]	621	SW-31	1700-III 16-VI	210-III 11.0-VI	50 100[1]	TVS-III 16-VI	TVS-III 11.0-VI		
Cobalt	26	SW-31							
Copper	114	SW-67	18[5]	12[5]		TVS	TVS	TVS	TVS
Cyanide	12200	SW-67	22	5.2		5	5	5	5
Iron	57100	SW-67		1000	300[3]		1000		300
Lead	73.8	SW-67	82[5]	3.2[5]	50	TVS	TVS	TVS	TVS
Lithium	100	SW-33, 46,66 67,68,69,70							

TABLE 6-3
COMPARISON OF MAXIMUM SURFACE WATER VALUES
FOR METALS TO FEDERAL AND STATE WATER QUALITY STANDARDS (μg/l)
(Continued)

Parameter	Maximum Value Reported[a]	Location	FEDERAL STANDARDS			STATE STANDARDS			
			AWQC for Protection of Aquatic Life[b]			Biological Parameters for Aquatic Life[d]		Stream Segment Standard[e]	
			Acute	Chronic	MCL[c]	Acute	Chronic	Acute	Chronic
Magnesium	27700	SW-31							
Manganese	830	SW-44			50[3]				50
Mercury	1270	SW-44	2.4	0.012	2			.01	
Molybdenum	500	SW-33							
Nickel	67.1	SW-67	1400[5]	160[5]		TVS	TVS	TVS	TVS
Selenium	20	SW-33	260	36	10	135	17	10	
Silver	70	SW-33	4.1[5]	0.120[5]	50	TVS	TVS	TVS	TVS
Thallium	10	SW-34	1400[2]	40[2]			15		
Tin	122	SW-44							
Vanadium	152	SW-67							
Zinc	1100	SW-66	120[5]	110[5]	5000[3]	TVS	TVS	TVS	TVS

TABLE 6-3
COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR METALS TO FEDERAL AND STATE WATER QUALITY STANDARDS (µg/l)
(Concluded)

Explanation of Table:

(a) Maximum Value Reported is for Total Recoverable Metals as reported in Appendix C of Final Phase III RFI/RI Work Plan for OU1 (EG&G 1990b); values reported as either 1) analyzed but not detected or 2) rejected, were not considered.
(b) EPA Quality Criteria for Protection of Aquatic Life, 1986.
(c) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990).
(d) CDH/WQCC, Colorado Water Quality Standards 3.1.0 (5 CCR 1002-8) 1/15/1974, amended 9/30/1989 (Environmental Reporter 726: 1001-1020: 6/90).
(e) CDH/WQCC, Classifications and Numeric Standards for S. Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin 3.8.0 (5 CCR 1002-8) 4/6/1981, amended 2/15/90.

AWQC = Ambient Water Quality Criteria
MCL = Maximum Contaminant Level
SDWA = Safe Drinking Water Act
TVS = Table Value Standard
WQCC = Water Quality Control Commission

(1) SDWA - MCL from EPA National Primary and Secondary Drinking Water Regulations - 40 CFR Parts 141, 142, and 143; Final Rule Effective, July 30, 1992.
(2) Insufficient data to develop criteria; Lowest Observed Effects Level (LOEL).
(3) Secondary MCL.
(4) Standards given for arsenic(III) and arsenic(V); chromium (III) and chromium(VI).
(5) Hardness-dependent criteria.

Barium

In general, the physical and chemical properties of barium are such that it is relatively non-toxic under usual marine and fresh water conditions, and therefore a criterion for aquatic life has not been promulgated. Although many barium salts are soluble in water and are reported to be poisonous, barium ions are thought to be rapidly precipitated or removed via adsorption and sedimentation. In most natural waters, there is sufficient sulfate or carbonate to precipitate the barium present as an insoluble, non-toxic compound. Experimental data indicate that soluble barium concentration in fresh and marine water would have to exceed 50 mg/l before toxicity to aquatic life would be expected. Criteria have been set for the protection of human health: 1.0 mg/l for water and fish ingestion, and the same (1.0 mg/l) as a drinking water MCL.

Beryllium

Based on available data, beryllium has been shown to be toxic to freshwater aquatic life at low concentrations. Acute toxicity occurs at concentrations as low as 130 ug/l, and chronic toxicity at 5.3 ug/l. Hardness has been found to have a substantial effect on acute toxicity. Species that are more sensitive to beryllium than those tested would experience toxic effects at lower concentrations.

Chromium(VI)

The toxicity of chromium is largely due to its oxidizing action in its hexavalent state (as chromic oxide, chromate, or dichromate) and its easy permeation of biologic membranes (NRC 1974). Acute toxicity values for chromium(VI) are available for freshwater animal species in 27 genera; these values range from 23.07 μg/l for a cladoceran to 1,870,000 μg/l for a stonefly. These species include a wide variety of animals that perform a wide spectrum of ecological functions. Daphnids are especially sensitive. The few data that are available indicate that the acute toxicity of chromium(VI) decreases as hardness and pH increase.

The chronic value for both rainbow trout and brook trout is 264.6 μg/l; while the chronic value for fathead minnow is 1,987 μg/l. Chronic tests using chinook salmon show a reduction in growth at low concentrations (16 μg/l). Chronic values in soft water for daphnids range from <2.5 to 40 μg/l and acute-chronic ratios range from 1.130 to >9.680 μg/l. Green algae are quite sensitive to chromium(VI). The bioconcentration factor (BCF) for rainbow trout is less than 3.

Copper

The toxicity of copper to aquatic organisms is due primarily to the cupric (Cu^{2+}) ion and possibly to some of the hydroxy complexes. Concentrations of copper ranging from 1 to 8,000 μg/l inhibit growth

of various aquatic plant species. Sensitivities for aquatic invertebrates and fish are similar to those for plants. Acute toxicity data are available for species in 41 genera of freshwater animals. At a hardness of 50 mg/ℓ, the genera range in sensitivity from 16.74 μg/l for Ptychocheilus to 10,240 μg/l for Acroneuria. Acute toxicity generally decreases as water hardness increases. Additional data for several species indicate that toxicity also decreases with increases in alkalinity and total organic carbon. Chronic values are available for 15 freshwater fish species and range from 3.873 μg/l for brook trout to 60.36 μg/l for northern pike. Fish and invertebrate species seem to be equally sensitive to the chronic toxicity of copper.

Protection of animal species appears to offer adequate protection of plants. Copper does not appear to bioconcentrate very much in the edible portion of freshwater aquatic species. Many animals have some ability to cope with excess copper through excretion (Rand and Petrocelli 1985). In animals where copper is not excreted, copper will accumulate in tissues, especially in the liver.

Cyanide

The acute toxicity of free cyanide (the sum of cyanide present as HCN and CN^-, expressed as CN) to various freshwater species involved in diverse community functions ranged from 44.73 μg/l to 2,490 μg/l. All of the species with acute sensitivities above 4 μg/l were invertebrates. A long-term survival and a partial and life-cycle test with fish gave chronic values of 13.57, 7.849, and 16.39 μg/l, respectively. Chronic values for two freshwater invertebrate species were 18.33 and 34.6 μg/l. Freshwater plants were affected at cyanide concentrations ranging from 30 μg/l to 26,000 μg/l.

Lead

The acute toxicity of lead to several species of freshwater animals has been shown to decrease as the hardness of water increases. At a hardness of 50 mg/l, the acute sensitivities range from 142.5 μg/l for an amphipod to 235,900 μg/l for a midge. Data on the chronic effects of lead on freshwater animals are available for two fish and two invertebrate species. The lowest and highest available chronic values (12.26 and 128.1 μg/l) are both for a cladoceran, but in soft and hard water respectively. Freshwater algae are affected by concentrations of lead above 500 μg/l, based on data for four species. BCFs are available for four invertebrate and two fish species and range from 42 to 1,700.

Several enzymes are sensitive to lead at very low concentrations. Lead strongly inhibits several ATPases, lipoamide dehydrogenase, and aminolevulinic acid dehydratase, which is involved in the synthesis of heme (Rand and Petrocelli 1985). In vertebrate animals, lead poisoning is characterized by neurological defects, kidney dysfunction, and anemia.

Manganese

Generally, manganese does not constitute a toxicity problem in fresh water. Ions of manganese are rarely found at concentrations greater than 1 mg/l, and tolerance values range from 1.5 to 1000 mg/l. Permanganates have been known to kill fish in 8 to 18 hours at concentrations of 2.2 to 4.1 mg/l, but these compounds are not persistent because they are rapidly reduced and rendered non-toxic in the presence of organic matter. In marine waters, manganese is a major problem due to bioconcentration in edible portions of mollusks; bioaccumulation factors up to 12,000 have been reported.

No criteria for protection of aquatic life have been set; criteria for the protection of human health have been established at 50 ug/l for water and fish ingestion and 100 ug/l for fish consumption only. A secondary MCL standard for drinking water at 50 ug/l has also been established.

Mercury

Mercury is toxic to all forms of biota in aquatic ecosystems, although many factors (e.g., alkalinity, pH, and temperature) influence toxicity. The toxic action of mercury in plants and animals appears to involve cell membranes and their permeability. In mammals, early subacute poisoning generally has a neurological manifestation (Rand and Petrocelli 1985). Data are available on the acute toxicity of mercury(II) to 28 genera of freshwater animals. Acute values for invertebrate species range from 2.2 μg/l for Daphnia pulex to 2,000 μg/l for three insects. Acute values for fish range from 30 μg/l for the guppy to 1,000 μg/l for Mozambique tilapia. Few data are available for various organomercury compounds and mercurous nitrate, which are 4 to 31 times more acutely toxic than mercury(II).

Available chronic data indicate that methylmercury is the most chronically toxic of the tested mercury compounds. Tests on methylmercury with Daphnia magna and brook trout show chronic values less than 0.07 μg/l. For mercury(II), the chronic value for Daphnia magna is about 1.1 μg/l and the acute-chronic ratio (median lethal concentration sufficient to produce short term effects/concentration producing effects after long term exposure) is 4.5. In both a life-cycle test and an early life-stage test on mercuric chloride with the fathead minnow, the chronic value was less than 0.26 μg/l and the acute-chronic ratio was over 600.

Freshwater plants show a wide range of sensitivities to mercury, but the most sensitive plants appear to be less sensitive than the most sensitive freshwater animals to both mercury(II) and methylmercury. A BCF of 4,994 is available for mercury(II); BCFs for methylmercury range from 4,000 to 85,000.

Selenium

Although selenium can be quite toxic, it has been shown to be an essential trace nutrient for many aquatic and terrestrial species and has also been shown to ameliorate the effects of a variety of pollutants (e.g., arsenic, cadmium, copper, and mercury). Invertebrates have been shown to be both the most sensitive and the most resistant freshwater species to selenium(IV). Acute values for Daphnia spp. range from 6 µg/l to 3,870 µg/l for selenium(IV). Acute values in fish for selenium(IV) range from 620 µg/l for fathead minnow to 35,000 µg/l for carp. The final chronic value for selenium(IV) of 27 µg/l is based on sensitivities of rainbow trout. Based on data for three species, selenium(IV) was shown to be 5 to 32 times more toxic than selenium(VI). Although selenium(IV) appears to be more acutely and chronically toxic than selenium(VI) to most aquatic animals, this does not seem to be true for aquatic plants. Growth of several species of green algae were affected by concentrations ranging from 10 to 300 µg/l. BCFs that have been obtained for selenium (IV) with freshwater species range from 2 for the muscle of rainbow trout to 452 for the bluegill. Highest concentrations of selenium(IV) have been found in fish viscera, due to the uptake of selenium adhering to food.

Silver

Silver is one of the most toxic metals to freshwater aquatic life. The forms of silver that are commonly found in bodies of water and are not measured by the total recoverable procedure, such as the silver in minerals, clays, and sand, are forms that are less toxic to aquatic life and probably will not be readily converted to the more toxic forms under natural conditions. The forms of silver that are commonly found in bodies of water and are measured by the total recoverable procedure, such as the free ion and the hydroxide, carbonate, and sulfate salts, are forms that are more toxic to aquatic life or can be converted to the more toxic forms under natural conditions. The toxicity of silver is dependent on the hardness of the water, with acute toxicity apparently decreasing as hardness increases. At hardnesses of 50, 100, and 200 mg/l as $CaC0^3$, the concentration of total recoverable silver should not exceed 1.2, 4.1, and 13 µg/l, respectively, at any time, if aqautic life is to be protected.

Acute toxicity data for silver are available for 10 species of freshwater animals from 9 different taxonomic families that perform a wide variety of community functions. For the four invertebrate species tested, the acute values for silver range from 0.25 µg/l for Daphnia magna to 4,500 µg/l for the scud, Gammarus pseudolimnaeus. Most of the acute values for freshwater fish are for the rainbow trout and fathead minnow. The acute values in flow-through tests range from 3.9 µg/l for the fathead minnow in soft water to 280 µg/l for rainbow trout in hard water. The range of acute values for the fish species tested is much less than the range of acute values for invertebrate species.

Available data indicate that chronic toxicity to freshwater aquatic life may occur at concentrations as low as 0.12 μg/l. Chronic values from three chronic toxicity studies with rainbow trout ranged from 0.04 to 0.27 μg/l. Bioconcentration factors for three insect species were calculated to range from 15 to 240. The bioconcentration factor for bluegills exposed during a 28-day test was less than one. The adverse effect concentrations of silver on freshwater plants range from 30 to 7,500 μg/l. The adverse efects of silver on freshwater plants are unlikely at concentrations which will not adversely affect freshwater animals.

Zinc

The levels of dietary zinc at which toxic effects are evident depend markedly on the concentration ratio of zinc to copper (Rand and Petrocelli 1985). Zinc is also a metabolic antagonist of cadmium, so that high zinc intakes in animals afford some protection against cadmium exposure. Acute toxicity values are available for 43 species of freshwater animals. Data indicate that acute toxicity generally decreases as hardness increases. When adjusted to a hardness of 50 mg/l, sensitivities range from 50.70 μg/l for Ceriodaphnia reticulata to 88,960 μg/l for a damselfly. Additional data indicate that toxicity increases as temperature increases. Chronic toxicity data are available for nine freshwater species. Chronic values for two invertebrates range from 46.73 μg/l for Daphnia magna to >5,243 μg/l for the caddisfly, Clistoronia magnificia. Chronic values for seven fish species range from 36.41 μg/l for flagfish, Jordanella floridae, to 854.7 μg/l for the brook trout, Salvelinus fontinalis. The sensitivity range of freshwater plants is greater than that for animals. Growth of the alga, Selenastrum capriocornutum, is inhibited by 30 μg/l; however, 4-day EC50s (median effective concentration sufficient to produce some response in 50 percent of test organisms) for several other species of green algae exceed 200,000 μg/l. Zinc bioaccumulates in freshwater animal tissues at 51 to 1,130 times the water concentration.

6.1.2.2 Radionuclides

Basic ecological research on radionuclides in the environment has a 40-year history resulting in sophisticated models for identification and prediction of the movement and concentration of specific radionuclides. The same is true for effects on humans resulting from exposure to both external and internal sources of radiation. Most of the scientific literature concerning radioecology has resulted from interaction between DOE-operated facilities and nearby universities.

The following discussion is a brief summary of the radionuclide literature reviewed. In general, transuranics tend to bind in the soils and sediments and have limited availability to biota. Bioaccumulation or concentration factors routinely are low between trophic levels. Data from Little et al. (1980) from the Rocky Flats Plant site indicate that radionuclide inventories (and thus radiation doses) in vertebrate populations are well below levels know to elicit effects.

Maximum values reported for radionuclides in soils, sediments, and surface water at OU1 are shown in Tables 6-4 and 6-5. Environmental action criteria similar to those used in Section 6.1.2.1 for metals are not available for radionuclides. Maximum values for radionuclides in surface water as reported for OU1 (EG&G 1990b) were compared to federal and state surface water quality standards to identify any contaminant levels of immediate concern (Table 6-5). Values for dissolved and total gross alpha, dissolved and total gross beta, total tritium, and total radium-226 exceeded surface water quality standards. Because of these exceedences, tritium and radium-226 are likely to be potential contaminants of concern. The maximum gross alpha value may also be of concern although it is not known to what specific radionuclide(s) this value is to be attributed. Based on the following cursory literature review, however, it seems unlikely that at the low dose levels reported, sufficient sensitive methods exist to distinguish adverse biological response from background "noise" (chance fluctuations due to climate, weather, human disturbance, etc.) at the Rocky Flats Plant Site.

Terrestrial Ecosystems

Historically, the principal reason for determining BCFs for terrestrial biota was to calculate the internal radiation dose to higher trophic levels at an equilibrium body burden from radionuclides assimilated from foodstuffs. For the most part, BCFs for mammals have been collected from fallout studies under widely varied habitat conditions (arctic, desert, temperature zone, and laboratory), and, consequently, there are few consistent generalizations. Concentration factors for cesium-137 typically show an increase from plants to mammalian herbivores as well as increases at the higher trophic levels. Ninefold increases in cesium-137 through the plant → mule deer → cougar food-chain were demonstrated in the work done by Pendleton et al. (1965). Also an increase of approximately 2- to 5-fold at each link in the lichen → caribou → wolf food-chain has been reported by Hanson et al. (1967).

Less comprehensive data are available for the other radionuclides, but it is evident that not all radionuclides are concentrated in food-chains and that different food-chains may exhibit markedly different concentration patterns for the same nuclide. The strontium-90 BCF for the plant → herbivore chain ranges from 0.02 to 8.4; while the BCFs for tritium, cobalt-60, and iodine-131 are less than 1.0, with the exception of 2.4 for seed → water → quail for cobalt-60 movement (Auerbach et al. 1973).

There have been few field studies on the comparative uptake of actinides (transuranics) by biota from contaminated soils. Uranium, thorium, and plutonium transfer in terrestrial food-chains has not been well studied because of the difficulty and expense of analyzing these elements at low levels in biota and the frequent high degree of variation in field data that complicates statistical comparisons between different actinides. Field studies that have been conducted on soil-plant-animal transfer suggest that

TABLE 6-4

SUMMARY OF MAXIMUM TOTAL RADIONUCLIDE VALUES IN SOILS AND SEDIMENTS*

Soil (Alluvium)	Maximum Concentration (pCi/g)	Sample #	Depth Interval (in ft.)
Gross Alpha	25 ± 10	BH1587	0.00 - 5.00
Gross Beta	24 ± 6	BH0187	.20 - 1.40
Uranium-233, -234	1.4 ± 0.2	BH6387	0.00 - 8.00
Uranium-238	1.4 ± 0.2	BH6387	
Strontium-89, -90	0.2 ± 0.5	BH6387	0.00 - 8.00
Plutonium-239	0.09 ± 0.13	BH1587	0.00 - 5.00
Americium-241	0.10 ± 0.12	BH1587	0.00 - 5.00
Cesium-137	1.3 ±1.0	BH0187	.20 - 1.40
Tritium	0.60 ± 0.22 (pCi/ml)	BH0187	.20 - 1.40
Total Uranium	2.8	BH6387	12.0 - 13.7
SEDIMENT			
Gross Alpha	77 ± 20	SD030	
Gross Beta	46 ± 6	SD030	
Uranium-233, -234	2.1 ± 0.4	SD025	
Uranium-235	0.1 ± 0.1	SD030	
Uranium-238	2.7 ± 0.4	SD025	
Strontium-89, -90	0.5 ± 0.8	SD030	
Plutonium-239	3.3 ± 0.1	SD025	
Americium-241	0.04 ± 0.03	SD002	
Cesium-137	0.7 ± 0.3	SD026	
Tritium	580 ± 450 (pCi/ml)	SD027	
Radium-226	1.4 ± 0.4	SD029	
Radium-228	2.5 ± 0.8	SD025	
Total Uranium	4.8		

* Values reported in Phase III RFI/RI Work Plan for OU1, Appendixes A and D (EG&G 1990b); rejected values were not considered.

TABLE 6-5

COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR RADIONUCLIDES TO FEDERAL AND STATE SURFACE WATER QUALITY STANDARDS

Analyte	Dissolved Concentration (pCi/l)[a]	Total Concentration (pCi/l)[a]	FEDERAL STANDARDS	STATE STREAM CLASSIFICATION STANDARDS [c]	
			SDWA Maximum Contaminant Level [b]	Basin Table D Radionuclide Standards	Table 2- Radionuclide Standard for Woman Creek
Gross Alpha	16.0 ± 11.0; 13.4 ± 5.1 (SW045)	230 ± 70 (SW067)	15 pCi/l		7 pCi/l
Gross Beta	15.9 ± 5.5 (SW069)	140 ± 20 (SW067)	4 mrem/yr		5 pCi/l
Strontium-89+90	0.3 ± 0.5 (SW032)	3.4 (SW031)		8 pCi/l	8 pCi/l[(1)]
Plutonium-239+240	2.6 ± 0.7 (SW045)	0.95 ± 0.05 (SW067)		15 pCi/l	
Americium-241	0.01 ± 0.01 (SW044, SW046, SW067)	0.32 ± 0.07 (SW067)		30 pCi/l	
Cesium-137	0.5 ± 0.6 (SW066)	0.7 ± 0.7 (SW069)			
Tritium	------	1100 ± 310 (SW046)		20,000 pCi/l	500 pCi/l
Radium-226	0.5 ± 0.3 (SW066)	6.1 ± 0.8 (SW067)	5 pCi/l[(2)]	5 pCi/l[(2)]	
Radium-228	------	11 ± 3 (SW067)			
Uranium-233+234	5.8 ± 0.8 (SW045)	7.5 ± 0.8 (SW067)			
Uranium-235	0.6 ± 0.2 (SW069)	0.7 ± 0.7 (SW045)			
Uranium-238	4.5 ± 0.5 (SW067)	11.0 ± 1.0 (SW067)			

Explanation of Table:

[a] Values as reported in Appendix C of Final Phase III Work Plan for OUI (EG&G 1990b); rejected values were not considered.

[b] EPA National Primary and Secondary *Drinking Water Regulations*, 40 CFR 141 and 40 CFR 143 (as of May 1990).

[c] Colorado Department of Health/Water Quality Control Commission, Classifications and Numeric Standards for S. Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin 3.8.0(5 CCR 1002-8) 4/6/1981; amended 2/15/1990.

[1] Standard for strontium-90.

[2] Standard for radium-226+228.

bioaccumulation of these elements does not occur. The Hakonson (1975) study of actinide levels in soils, plants, and animals indicates that, at the Trinity Site, residual plutonium was approximately 10 times lower in small rodents than in the corresponding grass samples. This same trend has been noted in other studies as well (Garten and Dahlman 1978, Garten et al. 1981). Bly and Whicker (1978) found that the mean ratio of plutonium-239 in arthropods to plutonium-239 in 0 to 3 cm soil at Rocky Flats Plant was 1.9×10^{-3}.

Little et al. (1980) conducted a comprehensive study in the grassland ecosystem around Rocky Flats. The overall conclusions mirror the previously mentioned works in that plutonium was not accumulated up through the food-chain. Additionally, the body burdens of biota were significantly lower than required to elicit a biological or ecological effect.

Most studies of radiosensitivities of soil fungal populations have been performed in the laboratory. Studies on the effects of irradiation of natural populations in the field have been rare and have suffered from inadequate controls (Stotsky and Mortenson 1959 and Stanovick et al. 1961).

A study by Edwards (1969) revealed distinct differences in radiosensitivities of various microarthropod groups, but all were killed at levels much lower than those lethal to microflora. Orbatid mites, the most radiation-resistant microarthropods, were killed by 200 kilorads. Auerbach et al. (1957) found that, with lower radiation doses, a lag effect exists in growth rates in certain microarthropods, such as Collembola. Cawse (1969) noted that bacteria are the most tolerant to radiation up to about 2.5 megarads. Fungi are resistant up to about 1 megarad (Johnson and Osborne 1964).

Fraley and Whicker (1973) found native shortgrass plains vegetation to be very resistant to chronic gamma radiation at exposure rates varying from 0.01 to 650 Roentgen/hr (R/hr, usually expressed as roentgen equivalent man-rem). One of the most resistant species was Lepidium densiflorum, which became dominant at exposure rates of 12 to 28 R/hr and was able to germinate, develop, and complete seed set at exposure rates greater than 28 R/hr. The level of radiation exposure in their study is many orders of magnitude greater than any encountered in the environment around facilities such as Rocky Flats.

A long-term project was initiated in 1968 at Oak Ridge National Laboratory (Styron et al. 1975) to assess effects of mixed beta and gamma radiation from simulated fallout on a grassland ecosystem. Extensive statistical analyses of data on numbers of individuals collected for each of 76 arthropod and 2 molluscan taxa have identified no lasting significant changes in similarity or species diversity of experimental versus control communities as the result of the long-term irradiation at low doses rates. Natural fluctuations in community dynamics obscured any possible radiation effects.

Mammal species and populations exhibit a similar resistance to chronic low-level exposures and even acute exposures required in excess of 100 rads to elicit reproductive, hemopoietic, or survivorships responses (Kitchings 1978).

Aquatic Ecosystems

Aquatic food-chain dynamics are similar to those previously described for terrestrial ones. On the whole, the actinides have no known biological function and do not show an affinity for muscle in higher trophic level organisms (Poston and Klopfer 1988). In a study conducted at the Savannah River Plant by Whicker et al. (1990), aquatic macrophytes were found to have the highest concentration ratio, primarily, the authors suggest, due to adsorption of sediment particulate to surfaces. All other trophic levels were found to have very low concentration ratios. In nearly all cases, concentrations of transuranics in vertebrate tissues were very low. Because of low food-chain transfer factors for most uranics, low concentrations in water, sediments, macrophytes, and invertebrates generally result in low concentrations of transuranics in vertebrate tissues (Bair and Thompson 1974; Eyman and Trabalka 1980).

Only 5 to 10 percent of the plutonium and americium in sediments in a process waste pond on the Hanford Reservation were found to be available for foodweb transfer (Emery et al. 1975). The remaining fraction appeared to be tightly bound to particles and would be transported ecologically in particulate form. Watercress had a plutonium concentration about equal to that found in the sediments, while dragonfly larvae and snails had americium levels approximating levels in the sediments. All remaining biota had plutonium and americium concentrations which were generally well below those of the sediments. Goldfish in the pond concentrated small amounts of both isotopes.

With respect to the distribution of several long-lived radionuclides within aquatic ecosystems, the work of Whicker et al. (1990) tends to confirm and strengthen the concept that many radionuclides tend to reside entirely in the sediments. It appears that this is true for cesium-137 and the transuranium elements. The rule also seems to hold for different types of systems with widely varying limnological properties. As a consequence, only a very small fraction of the total system inventory can reside in the biotic components. For radionuclides that tend to sorb strongly to sediments, this distribution can probably be extended to most freshwater ecosystems.

6.1.2.3 Organic Compounds

Most of the organic compounds found at OU1 (Table 6-1) are on the RCRA Appendix VIII and IX Lists, the Superfund Target Compound List, and the EPA Clean Water Act Priority Pollutants Compounds List, and each is known to cause adverse acute and chronic effects on aquatic life, depending on its concentrations. Chemicals which are readily accumulated by aquatic biota and are persistent in

aqueous media (e.g., petroleum distillates) will require evaluation of their potential adverse effects on site-specific biota. While there is no history of their disposal, detection of pesticides, PCBs, or dioxins in the Phase III analytical program for abiotic media would also warrant further consideration in this environmental evaluation. Locations of elevated levels of such organic chemicals in groundwater will warrant evaluation due to the potential interaction with surface water and subsequent potential for exposure to receptor organisms.

As shown on the Table 6-6, maximum levels for some of the organic compounds (e.g., carbon tetrachloride, trichloroethene, and tetrachloroethane) were above federal MCLs and federal water quality criteria for protection of human health. Although these same values are below AWQC for protection of aquatic life, these compounds will require closer evaluation of their potential to cause adverse effects on aquatic ecosystems.

Maximum values for organic compounds in soils and sediments (Table 6-7) were compared to RFI Guidance environmental action criteria (U.S.EPA 1989c). As these are human health-based criteria, a safety factor of 100 was applied based on the assumption that biota are 100 times more sensitive than humans. Reported maximum values in soils and sediments at OU1 were well below those criteria that were available. Volatile organic compounds in soils and sediments are generally not of immediate concern insofar as causing adverse effects on terrestrial biota, due to their tendency to volatilize.

6.1.3 Protected Wildlife, Vegetation, and Habitats

6.1.3.1 Wildlife

The U.S. Fish & Wildlife Service has identified several listed endangered or threatened wildlife species which could possibly occur in the Rocky Flats Plant area. However, none is expected to occur because of lack of habitat. These species include the endangered bald eagle (Haliaeetus leucocephalus), the two threatened subspecies of peregrine falcon (Falco peregrinus tundris and F. p. anatum), the endangered whooping crane (Grus americana), and the endangered black-footed ferret (Mustela nigripes).

The bald eagle is primarily a winter resident around rivers and lakes, and the closest known nesting pairs are found at Barr Lake, 25 miles to the east of Rocky Flats. Although the Rocky Flats Plant Site lacks suitable bald eagle nesting habitat, bald eagles have been observed over the plant site, and one pair has been observed feeding regularly at Great Western Reservoir, located approximately 0.4 miles east of the site.

TABLE 6-6
COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR ORGANIC COMPOUNDS TO FEDERAL AND STATE WATER QUALITY STANDARDS

Parameter	Maximum Value Reported Concentration[a]	Location	Federal Standards					
			CWA AWQC for Protection of Aquatic Life [b]		CWA Water Quality Criteria for Protection of Human Health [b]		SDWA Maximum Contaminant Level [c]	SDWA Maximum Contaminant Level (proposed) [d]
			Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only		
Volatile & Semivolatile Organics								
Methylene chloride	21.0 µg/l	SW-045						
Acetone	28.0 µg/l	SW-044						
Carbon tetrachloride	6.0 µg/l	SW-032, SW-045	35.2 mg/l[(1)]		400 ng/l**	6.94 µg/l**	5 µg/l	
Trichloroethene	26.0 µg/l	SW-032	45 mg/l[(1)]	21.9 mg/l[(1)]	2.7 µg/l**	80.7 µg/l**	5 µg/l	
Tetrachloroethene	128.0 µg/l	SW-045	5.28 mg/l[(1)]	840 µg/l[(1)]	800 ng/l**	8.85 µg/l**	5 µg/l	
Toluene	12.0 µg/l	SW-045	17.5 mg/l[(1)]		14.3 mg/l	424 mg/l		1 mg/l
Anions								
Nitrate + nitrate-nitrogen	424 mg/l	SW044						10 mg/l
Chloride	160 mg/l	SW044					250 mg/l*	
Sulfate	94 mg/l	SW044 SW066					250 mg/l*	
TDS	580 mg/l	SW031	SS	SS	250 mg/l		500 mg/l*	

TABLE 6-6
COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR ORGANIC COMPOUNDS TO FEDERAL AND STATE WATER QUALITY STANDARDS
(Continued)

Parameter	Statewide Standards CDH/WQCC[e]			CDH/WQCC Stream Segment Classification and Water Quality Standards[f]			
		Table C Aquatic Life				Stream Segment Table	
	Tables A, B Carcinogenic Noncarcinogenic [2]	Acute Value	Chronic Value	Tables A, B[2]	Table C Fish & Water Ingestion	Acute Value	Chronic Value
Volatile & Semivolatile Organics							
Methylene chloride							
Acetone							
Carbon tetrachloride	5 µg/l	35.2 mg/l		5 µg/l			
Trichloroethene	5 µg/l	45 mg/l	21.9 mg/l	5 µg/l			
Tetrachloroethene	10 µg/l	5.28 mg/l	840 µg/l	10 µg/l	800 ng/l		
Toluene	2.42 mg/l	17.5 mg/l		2.42 mg/l			
Anions							
Nitrate + nitrate-nitrogen							
Chloride							3 µg/l
Sulfate							250 mg/l
TDS							

TABLE 6-6

COMPARISON OF MAXIMUM SURFACE WATER VALUES FOR ORGANIC COMPOUNDS TO FEDERAL AND STATE WATER QUALITY STANDARDS (Concluded)

Explanation of Tables:

[a] Phase III RFI/RI Work Plan for OU1, Appendix C (EG&G 1990b); values reported as either 1) analyzed but not detected or 2) rejected, were not considered.
[b] EPA, Quality Criteria for Protection of Aquatic Life, 1986b.
[c] EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990).
[d] EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143, Final Rule, effective July 30, 1992.
[e] CDH/WQCC, Colorado Water Quality Standards 3.1.0 (5 CCR 1002-8) 1/15/74; amended 9/30/89 (Environmental Reporter 726:1001-1020:6/1990).
[f] CDH/WQCC, Classifications and Numeric Standards for S. Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin 3.8.0 (5 CCR 1002-8) 4/6/1981, amended 2/15/90.

AWQC = Ambient Water Quality Criteria
CDH = Colorado Department of Health
SDWA = Safe Drinking Water Act
SS = Species Specific
TDS = Total Dissolved Solids
WQCC = Water Quality Control Commission

(1) Criteria not developed, value presented is lowest observed effects level (LOEL)
(2) In the absence of specific numeric standards for non-naturally occurring organics, the narrative standard is interpreted as zero with enforcement based on practical quantification levels (PQLs) as defined by CDH/WQCC or EPA.

* Secondary maximum contaminant level
** Human health criteria for carcinogens reported for three risk levels. Value presented is the 10-5 risk level.

TABLE 6-7

COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES
FOR ORGANIC COMPOUNDS TO ENVIRONMENTAL ACTION CRITERIA

Parameter	Soil and Sediment Environmental Action Criteria[a] (µg/kg)	Sediment Concentration (µg/kg) (Sample #)[b]	Soil	
			Rocky Flats Alluvium Concentration (µg/kg) (Sample #) [Depth Interval (ft.)][c]	Colluvium Concentration (µg/kg) (Sample #) [Depth Interval (ft.)][c]
Volatile Organics				
Chloromethane	---	60 (SD029)		
Acetone	8,000,000	89.0 (SD014)	78.0 (BH1587) (0.00-5.00)	
Chloroform	110,000	18 (SD030)	---	
Trichloroethene	64,000	8 (SD031)	---	
Methylene Chloride	---		30 (BH6387) (12.00-13.70)	83.0 (BH0687) 24.10-25.50
2 - Butanone	---		---	390.0 (BH0987) 6.03-6.90
1,1,1-Trichloroethane	7,000,000		---	47.0 (BH5787) 4.0-5.80
Tetrachloroethene	---		---	96.0 (BH5787) 8.00-10.00
Semivolatiles				
bis(2-Ethylhexyl)Phthalate	83,000	---	1900 (BH1587) 0.0-5.00	5,023 (BH0287) 0.00-11.80
Diethyl Phthalate	6,000,000	---	---	29.0 (BH1487) 2.00-2.90

TABLE 6-7

COMPARISON OF MAXIMUM SOIL AND SEDIMENT VALUES
FOR ORGANIC COMPOUNDS TO ENVIRONMENTAL ACTION CRITERIA
(Concluded)

Parameter	Soil and Sediment Environmental Action Criteria[a] (µg/kg)	Sediment Concentration (µg/kg) (Sample #)[b]	Soil	
			Rocky Flats Alluvium Concentration (µg/kg) (Sample #) [Depth Interval (ft.)][c]	Colluvium Concentration (µg/kg) (Sample #) [Depth Interval (ft.)][c]
di-n-Butyl Phthalate	8,000,000	---	---	3,643 (BH0287) 0.00-11.80
di-n-Octyl Phthalate	---	---	---	265 (BH1387) 10.10-11.56
Anions	---	---		
Sulfide			0.0-8.00	<200,000

Explanation of Tables:

(a) Risk criteria are the lowest criteria reported for Health-Based Criteria for Systemic Toxicants and Carcinogens (Tables 8-6 and 8-7 in EPA 1989c). Criteria reported in Tables 8-6 and 8-7 are reduced by 100 to provide a safety factor to biota.

(b) Values reported in Appendix D of the Final Phase III RFI/RI Work Plan for OU1 (EG&G 1990b); values reported as either 1) analyzed but not detected or 2) rejected, were not considered.

(c) Values reported in Appendix A of the Final Phase III RFI/RI Work Plan for OU1 (EG&G 1990b); values reported as either 1) analyzed but not detected or 2) rejected, were not considered.

The whooping crane passes through Colorado during its spring and fall migrations. Whooping cranes blown off their migration course could use the Rocky Flats area as a night roost. These birds prefer large marshes and wetlands in broad open river bottoms and prairies. Such habitat is not present at Rocky Flats.

The two subspecies of peregrine falcon may occasionally occur in the Rocky Flats area as they hunt for prey. Nesting preferences are high cliff sides and river gorges, both of which are absent at Rocky Flats. However, nesting sites have been recorded about 4 to 5 miles west of the site.

The historical geographic range of the black-footed ferret coincides with that of prairie dogs, a principal prey species. Although black-footed ferret populations are now extinct in the wild, large prairie dog towns sufficient to support a black-footed ferret population (>80 acres for black-tailed prairie dogs), if found at Rocky Flats, would be surveyed by approved methods (U.S. Fish and Wildlife Service 1986).

Several additional species are of special interest to the State of Colorado because they are endangered in the state, are game species, have small and/or declining populations, or are pest/nuisance species (Colorado Division of Wildlife 1981, 1982a, 1982b and 1985). These species will be identified and investigated during Task 2 and will be considered in the development of on-site food webs.

6.1.3.2 Vegetation

Ten federally-listed or -proposed plant species occur in Colorado, all of which are western slope species. None of these is known or expected to occur on or near Rocky Flats. A number of candidate species for federal listing are known to occur in Jefferson and Boulder Counties, but have not been identified at Rocky Flats.

6.1.3.3 Wetlands

Numerous regulations and acts have been promulgated to protect water-related resources, including wetlands. Wetlands play an important role in ecosystem processing and in providing habitat to a variety of plant and animal species. An assessment of Rocky Flats wetlands was completed in 1989 (EG&G 1990a); these wetlands currently fall under the jurisdiction of the U.S. Army Corps of Engineers. Wetlands occur along Woman Creek, portions of the South Interceptor Ditch, and at Ponds C-1 and C-2. DOE activities with a potential to impact wetlands will follow regulations designed for their protection.

6.2 ENVIRONMENTAL EVALUATION TASKS

An environmental evaluation at OU1 is necessary for Rocky Flats Plant to meet the requirements of Sections 121(b)(1) and (d) of CERCLA and Section 300.430(d) of the National Oil and Hazardous Substances Pollution Contingency Plan (55 FR 8666; 3/8/1990). An environmental evaluation, in conjunction with the human health risk assessment, is required to ensure that remedial actions are protective of human health and the environment. Guidelines for conducting this evaluation, which is also called an ecological assessment, are provided by EPA in Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (U.S. EPA 1989b). Additional guidance is derived from EPA's Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference Document (U.S. EPA 1989a) and other guidance documents (Table 6-8).

The environmental evaluation is both a qualitative and quantitative appraisal of the actual or potential injury to biota other than humans and domesticated species due to contamination at OU1. The environmental evaluation is intended to reduce the inevitable uncertainty associated with understanding the environmental effects of contaminants present in OU1 and to give more definitive boundaries to that uncertainty during remediation.

The following plan for OU1 provides a framework for the review of existing data, the conduct of subsequent field investigations, and the preparation of the contamination assessment. Methodologies for the ecological and ecotoxicological field investigations (Tasks 3 and 9) are described in the Field Sampling Plan presented in Subsection 6.3.

Several of the tasks presented in the following plan will require coordination between the various operable units. In order to assure an integrated effort and to provide a means for obtaining input from regulatory agencies throughout the preliminary planning and implementation tasks, a Technical Working Group will be formed. As participants in this group, representatives from EG&G, DOE, and each of the regulatory review agencies will be involved in activities such as the determination of selection criteria for contaminants of concern, key receptor species and reference areas, and decisions regarding the use of existing data.

6.2.1 Task 1: Preliminary Planning

This task includes a definition of the study area, a determination of the scope of the environmental evaluation, identification of DQOs, and development of a plan for obtaining consensus on selection criteria for contaminants of concern, key receptor species, reference areas, and the field sampling approach/design. The scope of the environmental evaluation will describe the kind and amount of information that will be collected in the study. The biological parameters that are to be measured, estimated, and calculated will be described. The time period and boundaries of the evaluation will be

TABLE 6-8

EXAMPLES OF EPA AND DOE GUIDANCE DOCUMENTS AND REFERENCES FOR CONDUCTING ENVIRONMENTAL EVALUATIONS

Barnthouse, L.W., G.W. Suter, S.M. Bartell, J.J. Beauchamp, R.H. Gardener, E. Linder, R.V. O'Neill and A.E. Rosen. 1986. User's Manual for Ecological Risk Assessment. Environmental Sciences Division. Publication No. 2679, ORNL-6251.

U.S. DOE. 1988. Comprehensive Environmental Response, Compensation, and Liability Act Requirements. DOE Order 5400.YY. Draft, September 1988.

U.S. DOE. 1988. Radiation Effluent Monitoring and Environmental Surveillance. DOE Order 5400.XY, Draft, September 1988.

U.S. DOE. 1990. Radiation Protection of the Public and the Environment. DOE Order 5400.5

U.S. EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. Interim Final. Office of Emergency and Remedial Response, Washington D.C., EPA/540/g-89/004.

U.S. EPA. 1988. Superfund Exposure Assessment Manual. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-88/001.

U.S. EPA. 1988. Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/2-88/003.

U.S. EPA. 1989. Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual. Interim Final. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-89/001.

U.S. EPA. 1989. Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference Document. Office of Research and Development. EPA/600/3-89/013.

U.S. EPA. 1989. Exposure Factors Handbook. Office of Health and Environmental Assessment. Washington, D.C. EPA/600/8-89/043.

U.S. EPA. 1990. Guidance for Data Useability in Risk Assessment. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-90/008.9.2.1 Task 1: Preliminary Planning.

designated. Depending on the available pathways for exposure and the habitats potentially exposed to contamination, the study area for this ecological assessment may extend beyond the boundaries of each IHSS and the 881 Hillside area.

6.2.1.1 Selection Criteria for Contaminants of Concern

Because not all contaminants found at OU1 will have adverse effects on biota, the list of chemicals to be evaluated can be narrowed. Chemical and species-specific criteria (e.g., likelihood of exposure) will be used for selecting those contaminants that are of particular concern from an ecological perspective at OU1. Chemical, physical and toxicological criteria will be used in selecting contaminants of concern. Selection of these specific criteria will be developed in consultation with EPA and the State. Examples of the potential criteria to be evaluated in selecting contaminants of concern are shown in Table 6-9.

Although the selection process for contaminants of concern parallels that for the Human Health Risk Assessment, the lists may differ somewhat based on contaminant fate and transport characteristics and species-specific toxicities. The process for selecting contaminants of concern is currently being developed as a Standard Operating Procedure (SOP). Selection of the contaminants of concern will be evaluated in accordance with EPA guidance (U.S. EPA 1989b). An appropriate scoring system will be used to quantify the selection as much as possible. The selection process for these criteria will take into account the limited data that are available to quantify some of these factors (e.g., concentrations detected on site; frequency of detection). In these cases, a weighting factor will be used to assign such criteria a low reliance. The screening values for each the criteria will be used as tools to help select chemicals that need further assessment. They will not be used as limits which indicate absolute "no adverse effects" levels. Actual site-specific conditions will determine the potential for adverse effects in receptor species at OU1.

6.2.1.2 Identification of Key Receptors

Key receptors are those species or taxon which are or may be sensitive to the particular contaminants of concern. Organisms at each trophic level within a food web differ in their sensitivity and the ways they take in, accumulate, metabolize, distribute, and expel contaminants. The susceptibility of a particular organism also varies with the mechanism through which contaminants are taken up from the environment. In general, the following criteria determine the susceptibility of the receptor to a particular contaminant (U.S. EPA 1989b):

- The rapidity with which the contaminant is absorbed from the environment
- Sensitivity of the receptor's tissues to the dosage incurred
- Relationship between tissue sensitivity and the expression of symptoms of toxic injury
- The rapidity of repair or accommodation to the toxic injury

TABLE 6-9

POTENTIAL SELECTION CRITERIA FOR CONTAMINANTS OF CONCERN

Concentrations detected on site
Frequency of detection
Historical disposal information
- Type
- Quantity

Mobility in environmental media
Chemical fate (transport)
- Adsorption coefficient
- Partition coefficient (water-octanol)
- Water solubility
- Vapor pressure

Persistence
- Biodegradation
- Chemical degradation

Bioaccumulation potential
Bioavailability
Biotransformation potential
Background concentrations
Biochemistry
- Essential nutrient
- Enzyme inhibitor

Toxicity
Treatability

Selection of key receptors will depend on the ability to detect toxic injury in the organism or subsequent adverse effects to the population. National standards on the definitions of injury to biological receptors are found in the Natural Resource Damage Assessment Rule [40 CFR Subtitle A Section 11.62 (f)]. These include death, disease, behavioral abnormalities, cancer, physiological malfunctions, and physical deformation. Additional methods for detecting injury to biological resources are provided in the Type B Technical Information Document: Injury to Fish and Wildlife Species (U.S. DOI 1987). The procedures described in these documents provide a framework for determining what categories of effects might be observed in the field during the site visit and subsequent surveys and for selecting appropriate study methods to establish relationships between contaminant distribution and concentration in the physical environment and biological consequences in the receptor organisms and populations (Reagan and Fordham 1991). By using this approach to focus efforts on examining specific effects in key receptors, costs and sampling efforts will be reduced.

The selection of key receptors is in part a subjective decision based on species dominance or judged importance in the food chain. Selection criteria for key receptors will include consideration of the following:

- Sensitivity to contaminants
- Listing as rare, threatened, or endangered by a governmental organization
- Game species
- A key component of ecosystem structure and function (e.g., abundant prey for other important species)

Additional criteria used in the selection of key receptors include habitat preferences, food preferences, and other behavioral characteristics which can determine population size and distribution in an area or significantly affect the potential for exposure. Key receptors may include game species such as mule deer (Odocoileus hemionus) which is mobile and has a large home range; or an organism that is sedentary or has a more restricted movement, such as plants, some invertebrates, and some small vertebrates. For contaminants that bioaccumulate, the effects are usually most severe for organisms at the top of the food chain (e.g., top predators). Examination of contaminant effects on these more mobile species may necessitate the integration of data from different OUs.

A checklist of OU1 biota will be developed in conjunction with the ecological field inventory. The initial list of key receptors will be chosen from the checklist based on the selection criteria and will include organisms from each trophic level. The documented selection analysis will include an evaluation of the receptor's relation to potential contaminant exposure through both direct contaminant accumulation from the abiotic environment and bioaccumulation through the food chain. Examples of key receptor species (or taxon) likely to be on this list are presented in Table 6-10. This list will be refined as

TABLE 6-10

POTENTIAL KEY BIOLOGICAL RECEPTORS FOR ASSESSMENT OF ECOLOGICAL IMPACTS FROM OU1

Community	Taxon
Periphyton	Green algae Blue-green algae
Benthic Macroinvertebrates	Mayflies (larvae) Caddis flies (larvae) Chironomids (larvae) Crayfish
Fish	Fathead minnow Bluegill
Reptiles	Garter snake Bull snake
Mammals	Deer mouse Northern pocket gopher Microtines Rabbit Coyote
Birds	Mourning dove Mallard Killdeer Red-winged blackbird Ring-necked pheasant Cormorant Blue heron Great-horned owl
Terrestrial Invertebrates	Earthworms Grasshoppers
Grasses	Western wheatgrass Blue grama Cheatgrass
Shrubs/Forbs	Snowberry Willows Bindweed Sunflower Cattails Pondweed
Microbial Populations	Entire population

information is evaluated on known contaminant effects on these species (or similar species) and the documented levels of contamination present at the site.

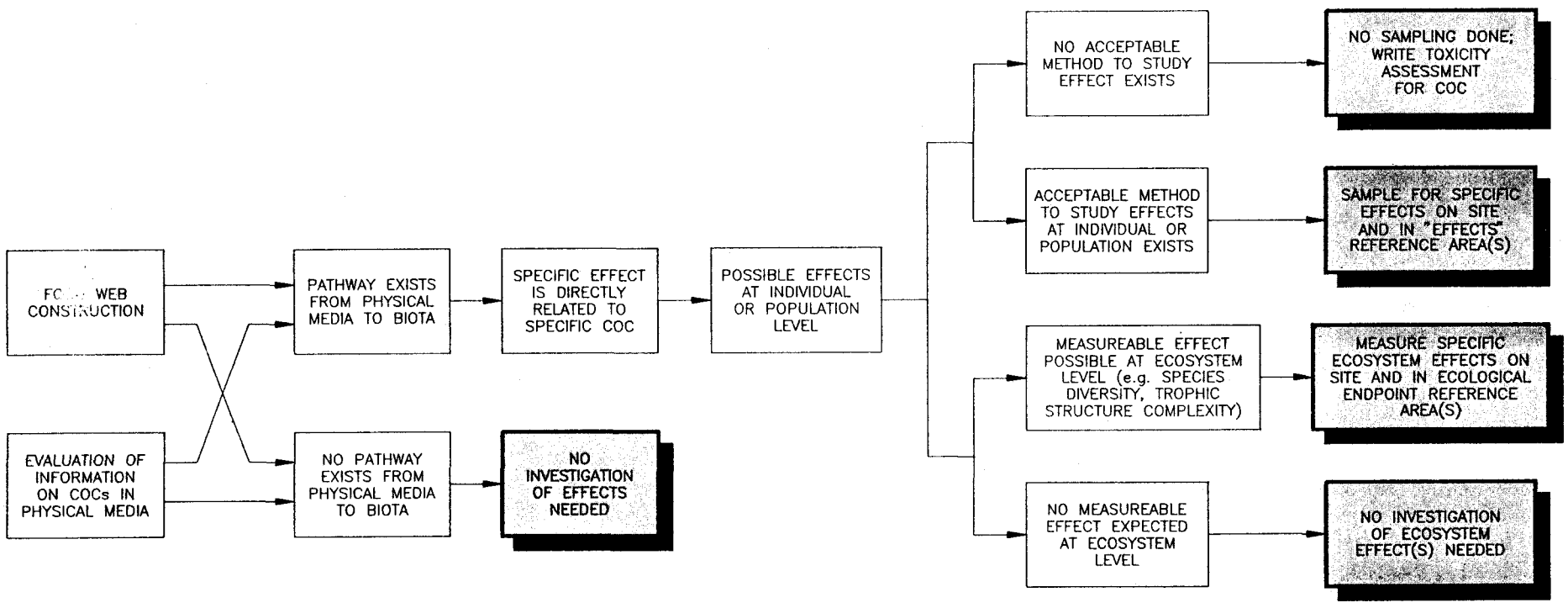
Key receptors will be selected from this list for subsequent detailed food web analyses and possible tissue sampling or other ecotoxicological analyses. Selection of key receptors for tissue analyses will depend on the receptor's suitability for sampling, sample size requirements, results of the preliminary exposure assessment, and expectation for finding contaminants in the tissues sampled (see Subsections 6.2.9 and 6.2.10). Final selection of the contaminants of concern and key receptors will provide the basis for the contamination assessment (Tasks 4 through 7). In the contamination assessment, food webs and contaminant exposure pathways will be developed for OU1. Information on these food webs will be used to relate quantitative data on contaminants in the abiotic environment to adverse effects in biota and to evaluate potential impacts to biota due to contaminant exposure.

6.2.1.3 Reference Areas

Determination of criteria for selection and sampling of reference areas will be coordinated between operable units and will be addressed in the SOPs. Reference areas will be identified as needed for terrestrial, wetland, and aquatic species, and will be selected based on measurement endpoints. Reference areas are likely to be selected in the northwestern portion of Rocky Flats Plant, away from potential effects associated with releases from either Rocky Flats or OU1. Additional off-site areas may also be selected, as appropriate.

Reference areas need not be selected where current and historical data are available to assess impacts from OU1 contaminants. Where such data are not available, one or more reference areas may be selected based upon their similarity to OU1, their lack of exposure to contamination from Rocky Flats or other sources, and the selected measurement endpoint. If more than one habitat or ecosystem type (e.g., terrestrial and aquatic) is to be assessed at OU1, comparable reference areas may be established for each, or a reference area may be selected containing those habitats or ecosystem types in a comparable distribution. For OU1, at least one reference area may be located upstream of the assessment area unless conditions indicate the area is unsuitable as a reference area. Data collected at the reference area will be compared where possible to values reported in the scientific literature to demonstrate that the data represent a normal range of conditions. Methods used to collect data at the reference area will be comparable to those used at OU1.

The decision process for using reference areas in the investigation of adverse effects from contamination at Rocky Flats is presented in Figure 6-2. As shown in this figure, a number of activities will take place prior to the selection of reference areas. These activities include the determination that:



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 1

PHASE III RFI/RI WORK PLAN

DECISION PROCESS FOR THE INVESTIGATION OF INDIVIDUAL, POPULATION, AND ECOSYSTEM LEVEL EFFECTS AND FOR THE USE OF REFERENCE AREAS FOR COC EFFECTS

FIGURE 6-2 MAY 1991

2506E003

- A pathway (inhalation, ingestion, etc.) exists for the movement of a contaminant of concern from the physical abiotic media to biota

- Acceptable methods are available to study the resultant effects of contamination at the individual, population, or ecosystem level (e.g., species diversity, trophic structure complexity)

Selection of a reference(s) area will ultimately depend on the specific effect or ecological endpoint that is to be measured. More than one reference area may be used depending on the effects to be studied. The selection of reference areas would be made to meet DQOs (U.S. EPA 1989b) and the selected assessment and measurement endpoints. Two basic criteria would be employed in the selection and establishment of reference areas:

- The reference areas will be similar to OU1 in terms of soil series, topography, aspect, vegetation, habitat types, and plant and animal assemblages.

- The reference areas, including vegetation and wildlife, have not been impacted by releases from OU1 or other Rocky Flats Plant operable units.

6.2.1.4 Data Quality Objectives

The DQO development process will follow the three steps recommended by EPA (1989a). Step I of the DQO process involves preparing definitions and concise DQOs. Examples of Step I program DQOs for this environmental evaluation include the following:

- Identify appropriate site-specific receptor species, contaminants of concern, and exposure pathways to determine if there is a potential for adverse effects to occur as a result of contamination. This step includes determination of relevant contaminant concentrations in biological tissues.

- Evaluate the potential for impacts to occur to biological resources outside the boundaries of OU1 or Rocky Flats Plant.

- Evaluate the need for remediation to protect the environment.

Steps II and III of the DQO process include identification of data uses and needs and design of the data collection program. Products of Step II include proposed statements of the type and quality of environmental data required to support the DQOs, along with other technical constraints on the data collection program. The objective of Step III is to develop data collection plans that will meet the criteria

and constraints established in Steps I and II. Step III results in the specification of methods by which data of acceptable quality and quantity will be obtained. The DQO development process will continue as scoping of the environmental evaluation becomes more refined. Additional Step I decision-type DQOs may be needed, or data collection-type DQOs may be modified based on Task 1 and Task 2 results and subsequent refinement of the field sampling plan.

6.2.1.5 Field Sampling Approach/Design

The Field Sampling Plan presented in Subsection 6.3 is designed to be flexible, so that it can be revised as additional data are collected. Flexibility in the Field Sampling Plan will ensure that field data collection activities will be comparable to and compatible with previous data collection activities performed at the site, while providing a mechanism for planning and approving new field activities. The Field Sampling Plan, in conjunction with SOPs for Ecology (Volume V-in preparation by EG&G), will provide guidance for all field work by defining the sampling and data-gathering methods to be used on the project.

6.2.2 Task 2: Data Collection/Evaluation and Conceptual Model Development

As an integral part of the RFI/RI process, Task 2 of the environmental evaluation will focus on accumulating and analyzing pertinent information on three major areas:

- Species, populations, habitats and food web interrelationships
- Types, distribution and concentrations of contaminants in the abiotic environment (e.g., soil, surface water, groundwater, and air)
- Preliminary determination of potential exposure pathways and potential contaminant effects on OU1 biota based on literature review

The principal subtasks in Task 2 include Literature Review and Site Characterization. These subtasks will be performed in conjunction with Task 3, Ecological Field Investigation. Information that will be developed from these tasks includes the following:

- Chemical Inventory/Contaminants of Concern - Existing information including that obtained on chemical contaminants from other investigations at Rocky Flats and other DOE facilities will be used in the development of a preliminary list of contaminants of concern.

- Initial toxicity test data - Preliminary data on the toxicity of potentially complex chemical mixtures in OU1 surface waters.

- Descriptive field surveys - Inventory of OU1 biota and locations of obvious zones of chemical contamination, ecological effects, and human disturbance.

- Species inventory - Plant and animal species known to occur within OU1 or to potentially contact contaminants at OU1 and their trophic relationships.

- Population characteristics - Information on the abundance of key species (see SOPs).

- Food habit studies - Available information from literature sources to supplement field observations and possible gut content analysis on key receptor species.

6.2.2.1 Literature Review

As an essential part of Task 2, a review of available documents, aerial photographs, and data relevant to the site will be completed. This will allow compilation of a database from which to determine data gaps and to provide evidence for a defensible field sampling program. Prior studies by DOE and the Rocky Flats Plant operating contractors will be reviewed and evaluated. Information to be reviewed will include the following:

- Project files maintained by Rockwell International and EG&G

- Project reports and documents on file at the Front Range Community College Library, at the Colorado Department of Health, and at the Colorado Division of Wildlife

- DOE documents and DOE orders

- The Phase I database

- The Rocky Flats EIS database

- Data from ongoing environmental monitoring and National Pollution Discharge Elimination System (NPDES) programs

- Studies conducted at Rocky Flats on radionuclide uptake, retention, and effects on plant and animal populations

- Scientific literature, including ecological and risk assessment reports, from other DOE facilities (Oak Ridge National Laboratory, Los Alamos, Hanford, Savannah River, Fernald)

If available and applicable, historical data will be used. Where the same methods are not used in the collection of new data, use of historical data will depend on the demonstrated comparability of the data collection methods. Where possible, analytical data files will be made available in an electronic file format.

6.2.2.2 Site Characterization

Environmental resources at the site will be characterized based on reviews of existing literature and reports, including results from the Phase III RFI/RI investigation, other operable unit RFI/RI investigations and the Task 3 ecological field investigation. The description of the site will be presented in terms of the following distinct resource areas:

- Meteorology/air quality
- Soils
- Sediments
- Geology
- Surface and groundwater hydrology
- Terrestrial ecology
- Aquatic ecology
- Protected/important species and habitats

The purpose of the site characterization is to describe resource conditions as they exist without remediation. The narrative with supporting data will include descriptions of each resource, with attendant tables and figures, as appropriate, to depict, in a concise and clear fashion, site conditions, particularly as they influence contaminant fate and transport.

Included in this task is the development of a community food web model (Reagan and Fordham 1991) to describe the feeding relationships of organisms at Rocky Flats Plant. Food web construction begins with gathering information to evaluate the food habits of species or species groups (e.g., grasshoppers) found or potentially occurring on site. Standard computer searches will be augmented with searches of local university libraries to locate any regionally pertinent studies on food habits. The preliminary list of important species, compiled from background information, will be completed based on observations of presence and abundance made during the ecological site surveys and on trophic level data obtained from the food web model. Based on the model, a modified list of species will be made using

toxicological information (toxicity assessment) to determine which species or species groups might be most affected or most sensitive to the chemical(s) of interest.

Data from past studies and preliminary data from current environmental studies will be used to better define the present distribution of contaminants in the abiotic environment and to develop an initial food web model. The food web model in conjunction with a preliminary pathways analysis will identify likely or presumed exposure pathways or combinations of pathways and receptor species at risk. Based on this preliminary information, the Task 3 and Task 9 field investigation sampling approach/designs may be revised.

6.2.3 Task 3: Ecological Field Investigation

The Phase I field investigation for OU1 consists of the following separate programs: (1) the air quality monitoring program, which will entail emissions estimation and modeling; (2) the soils, surface water, and groundwater sampling programs, which will be conducted as part of the Phase III RFI/RI activities; (3) and the terrestrial and aquatic biota sampling program, which will be conducted as part of this environmental evaluation.

6.2.3.1 Air Quality

A site-wide air quality monitoring program is being conducted at Rocky Flats (Section 2.3.6 in EG&G 1990b). Specific air monitoring is also being done at OU1. These data can be used to model airborne deposition and transport of contaminants through the food web to potential receptors. Such modeling could be performed where data in abiotic media are inadequate. Where the inhalation pathway is considered to be significant in the case of OU1 biota, a detailed pathways analysis and assessment of potential adverse effects using transport model data will be performed.

6.2.3.2 Soils

Site-specific soil data in the form of contaminants present in surficial deposits currently exist for the 881 Hillside area (Volume II, Appendix A, Final Phase III RFI/RI Work Plan, EG&G, 1990b). These data were collected as part of Phases I and II of the RFI/RI for 881 Hillside. The drilling was conducted to identify and characterize past waste disposal sites. Boreholes were drilled within and adjacent to the IHSSs, and soil samples were collected and analyzed for organics, inorganics, metals, and radionuclides. Sequences of Rocky Flats Alluvium, Colluvium, Recent Valley Fill, and Arapahoe Formation were sampled and tested in the field and in the laboratory. The geologic and hydrologic data from Phase I and II drilling programs provided the basic framework for defining a chemical/hydrologic/geologic model for the 881 Hillside area. Source contaminants and concentrations, as well as possible flow paths, rates, and accumulations, were preliminarily assessed to characterize the dynamic system.

Volatile organics data for soils previously collected from the 881 Hillside area were rejected during the data validation process because of inadequate sample size and cannot be used in a quantitative sense. Analytical results of the Phase III soil samples will be reviewed and interpreted for use in this environmental evaluation.

The Phase III RFI/RI work plan proposes an additional soil sampling program for the 881 Hillside area to further characterize the extent of contamination, gain additional hydrologic data, and resolve questions regarding the presence and concentration of volatile organics. Under the program, test wells will be designed to provide a continuous core of sediment, and will evaluate the Rocky Flats Alluvium, Colluvium, Recent Valley Fill, and upper section of the Arapahoe Formation. Soil samples will be analyzed for organics, inorganics, metals, and radionuclides.

As in prior programs, the soil sampling locations are placed in areas to characterize specific sites and regimens, and they do not form a random grid. However, sample density is considered sufficient to provide a clear picture of soil characteristics and contaminant concentrations for all soil types found in the 881 Hillside area. The range of substances to be tested (from the Hazardous Substance List) is also considered sufficient for the environmental evaluation.

Soil analysis results are related to surface and groundwater regimens. Fluids moving through the soils can act to leach contaminants and transport them through available flow paths and deposit them in downgradient environments. Soil analyses may help define extent of contaminant sources as well as areas of accumulation.

The near surface soil scrapings will be of prime importance for determining source contaminants for biota. This uppermost layer provides the major source of nutrient and contaminant uptake for the vegetation under study and is a source of potential contaminant ingestion to wildlife. Sampling and analysis programs proposed under the Phase III RFI/RI field investigation will be reviewed by the Technical Working Group and modified as necessary to ensure that sampling intervals, methods, and the analytical program are appropriate and meet DQOs of the environmental evaluation.

6.2.3.3 Surface Water and Sediments

The proposed Phase III surface water sampling and analytical program presented in the RFI/RI Work Plan for 881 Hillside area was evaluated with respect to this environmental evaluation. Sampling locations presented in the work plan are continuing to be sampled on a monthly basis through 1990 as part of the overall plant sampling program. All seeps and springs in the 881 Hillside area will be sampled as part of this ongoing program. Chemical results from the surface sampling locations will be reviewed and incorporated into the environmental evaluation.

Surface water and sediment samples are collected on a regular basis as part of ongoing investigations at OU1 as well as nearby OUs 2 and 5. The proposed investigation at OU5 includes extensive sampling along Woman Creek, the South Interceptor Ditch, and in Ponds C-1 and C-2. In addition, samples will be collected upstream of the Rocky Flats Plant to provide background data. Samples will be analyzed for metals, radionuclides, inorganics, and organics. Total organic carbon in soils and sediments and sediment grain size will be determined as part of the analytical program.

Surface water sampling and analytical results presented in the Final Phase III OU1 RFI/RI Work Plan will be evaluated with respect to the abiotic sampling programs planned in the nearby operable units to assure the abiotic data needs for the environmental evaluations at each of these OUs are addressed. Sampling locations and programs presented in each of these work plans will be integrated as part of the field sampling implementation program. Chemical results from the OU2 and OU5 surface sampling locations will be reviewed and incorporated into the OU1 environmental evaluation as needed.

6.2.3.4 Groundwater

The Phase III RFI/RI Work Plan for the 881 Hillside area provided a detailed discussion of the planned Phase III groundwater investigation and summarized the scope and results of previous Phases I and II groundwater studies conducted in 1987. The results of the Phase I and II investigations, along with planned Phase III activities for the 881 Hillside area, were reviewed to determine if any data gaps existed and should be resolved prior to implementing the Phase III program and environmental evaluation for the 881 Hillside area.

Data from the Phase III program will aid in characterizing the nature and areal extent of groundwater contamination in the vicinity of the site. The hydrogeologic information and laboratory analytical results from the planned Phase III boring and well installation program will likewise be used in the environmental evaluation. The above information will be used to assess the nature and extent of contamination in shallow groundwater and help identify exposure pathways for the environmental assessment.

Data from the Phase I OU5 RFI/RI Program and the Phase II OU2 RFI/RI Program will also aid in characterizing the nature and areal extent of groundwater contamination in the vicinity of the site. The hydrogeologic information and laboratory analytical results from these planned boring and well installation programs will likewise be incorporated in the OUI environmental evaluation where applicable. The information will be used to assist in determining the nature and extent of contamination in shallow groundwater and help identify exposure pathways for the environmental assessment.

6.2.3.5 Terrestrial and Aquatic Biota

Terrestrial and aquatic species in the Rocky Flats Plant area have been described by several researchers (Weber et al. 1974; Clark 1977; Clark et al. 1980; Quick 1964; Winsor 1975; CDOW 1981; CDOW 1982a, 1982b); most of these reports are summarized in the Final EIS (U.S. DOE 1980). In addition, terrestrial and aquatic radioecology studies conducted by Colorado State University (CSU) and DOE (Rockwell International 1986; Paine 1980; Johnson et al. 1974; Little 1976; Hiatt 1977), along with annual monitoring programs at Rocky Flats Plant, have provided information on the plants and animals in the area and their relative distribution.

Limited field surveys will be conducted in Task 3 to characterize current biological site conditions in terms of species presence, habitat characteristics and/or community organization. The emphasis will be to describe the structure of the biological communities at OU1 in order to identify potential contaminant pathways, biotic receptors, and key species.

Initial aquatic toxicity tests using Ceriodaphnia spp. and fathead minnows will be conducted at OU1 under Task 3. The technical objective of the toxicity tests is to provide a screening mechanism to aid in the determination of the nature and extent of contamination, particularly since there is the potential for exposure to mixtures of contaminants. EPA recognizes the usefulness of such toxicity testing as a means for integrating the effects of all toxic pollutants, which cannot be measured by chemical analysis. Standardized EPA acute and chronic test methods will be followed in accordance with NPDES toxicity testing procedures currently being used at Rocky Flats.

Vegetation

The objectives of the vegetation sampling program are to provide data for: (1) the description of site vegetation characteristics; (2) identification of potential exposure pathways from contaminant releases to higher trophic-level receptors; (3) selection of key species for contaminant analysis to determine background conditions for OU1; and (4) identification of any protected vegetation species or habitats.

A number of habitat types are expected to be found in the 881 Hillside area. Grasses characteristic of the short grass plains are expected to be abundant. Representative species include blue grama (Bouteloua gracilis), Junegrass (Koeleria cristata), dropseed (Sporobolus spp.), slender wheatgrass (Agropyron trachycaulum), and green needlegrass (Stipa viridula), which are interspersed with other grasses, shrubs, and a variety of annual flowering plants. Transects will be established on the 881 Hillside area (see Section 6.3.2.1) to collect phytosociological data on biomass and cover, shrub/tree density and frequency, and species presence.

Wetland Vegetation

Wetlands have been identified along Woman Creek and the South Interceptor Ditch (EG&G 1990a). These occur as linear wetlands that support hydrophytic vegetation species including sandbar willow (Salix exigua), american watercress (Barbarea orthoceras), and plains cottonwood (Populus sargentii). Other species associated with these wetlands include broad-leaf cattail (Typha latifolia), baltic rush (Juncus articus), cordgrass (Spartina pectinata), silver sedge (Carex praegracilis), and various bulrushes (Scirpus spp.). Transects will be established in adjacent wetland vegetation habitats at the designated aquatic sampling locations (see Section 6.3.2.2) to collect phytosociological data on biomass and cover, shrub density and frequency, and species presence.

Periphyton

The periphyton community is a closely-adhering group of organisms that form mat-like communities on rocks, other solid objects, or the stream bottom. The community is composed of algae, bacteria, fungi, detritus, and other macroscopic heterotrophic organisms. Because of the large surface-to-volume ratio of its constituents, periphyton have been found to be an excellent indicator community for accumulation of contaminants. Periphyton samples will be collected at designated locations presented in the Field Sampling Plan (see Section 6.3.2.2).

Periphyton communities provide a sensitive mechanism to detect changes in aquatic environments that result from the introduction of contaminants. Taxonomic composition and relative abundance of periphyton can be measured on natural substrates as well as standardized artificial substrates. On hard artificial substrates, data on algal abundance, biomass, and species composition will be obtained by removing the substrate and by scraping or brushing the flora from a measured area into a container.

Benthic Macroinvertebrates

Benthic macroinvertebrates may exist in rocky/gravelly substrates or as soft-bottom communities along portions of Woman Creek, the South Interceptor Ditch, and Ponds C-1 and C-2. The soft-bottom benthos are those macroscopic invertebrates inhabiting mud or silt substrates, whereas the immature stages of insects inhabit rock surfaces, rooted stems, and leaves or gravelly substrates. Because these communities are essentially stationary, they are good indicators of past and present habitat contamination. Additionally, their feeding methods (filtering microscopic organisms and fine materials, preying on smaller invertebrates, and grazing on periphyton), suggest that benthic species are ingesting other organisms that are potentially concentrating contaminants. Designated locations (see Section 6.3.2.2) in the South Interceptor Ditch, Woman Creek, and Pond C-1 will be sampled for benthic organisms.

Fish

Fish can be important components of ecological assessments because they are relatively long-lived, occupy upper trophic levels of aquatic ecosystems, and they may spend their entire lives in relatively small areas. Fish species representing both herbivores and carnivores are likely present in Woman Creek Drainage and Pond C-1 aquatic habitats and may demonstrate biomagnification of contaminants within the pond or creek ecosystem. Designated aquatic sampling locations (see Section 6.3.2.2) will be sampled for fish where the habitat is appropriate.

Terrestrial Wildlife

A field survey will be conducted to gather data on animal communities in the 881 Hillside area. The objective of the animal life survey is to: (1) describe the existing animal community in the 881 Hillside area; (2) identify potential contaminant pathways through trophic levels; (3) develop food web models including contribution from vegetation; (4) identify key species for potential collection and tissue analysis; and (5) identify any protected species.

The field survey as presented in the Field Sampling Plan (see Section 6.3) will document the presence of terrestrial species and allow for a general description of the community. Some species (e.g., songbirds, larger mammals, reptiles, and raptors) may use the area daily, seasonally or sporadically, or wander through as vagrants. Survey timing and techniques will consider these uses.

6.2.4 Contamination Assessment (Tasks 4 through 7)

The contamination assessment includes Tasks 4 through 7. The two major objectives of the contamination assessment are to:

- Obtain quantitative information on the types, concentrations, and distribution of contaminants in selected species, and

- Evaluate the effects of contamination in the abiotic environment on ecological systems.

Conducting a contamination assessment requires an evaluation of chemical and radiological exposures and the subsequent toxicological effects on key species. Of specific importance in the contamination assessment is the identification of exposure points, the measurement of contaminant concentrations at those points, and the determination of potential impacts or injury. Impacts may result from movement of contaminants through ecological systems or from direct exposure (inhalation, ingestion, or deposition).

The Contamination Assessment for OU1 will be based on existing environmental criteria, published toxicological literature, and existing, site-specific environmental evaluations. The program design will be integrated with other ongoing RFI/RI studies so that concentrations of contaminants in abiotic media can be related to contaminant levels and effects in biota. A preliminary contamination assessment will be made in Task 2 based on the site characterization and contaminant identification activities. The preliminary Task 2 assessment will be used to revise the Task 9 ecotoxicological field investigation sampling design. The contamination assessment process described in the following tasks will include the development of a site-specific pathways model to quantify the potential for contaminant exposure and adverse effects in biota.

The objectives and description of work for each of the contamination assessment tasks is described below.

6.2.5 Task 4: Toxicity Assessment

This assessment will include a summary of the types of adverse effects on biota associated with exposure to site-related chemicals, relationships between magnitude of exposures and adverse effects, and related uncertainties for contaminant toxicity, particularly with respect to wildlife. Ecological receptor health effects will be characterized using EPA-derived critical toxicity values when available in addition to selected literature pertaining to site- and receptor-specific parameters.

The toxicity assessment will provide brief toxicological profiles centered on health effects information on wildlife populations. The profiles will cover the major health effects information available for each contaminant of concern. Data pertaining to wildlife species will be emphasized, and information on domestic or laboratory animals will be used when wildlife data are unavailable. Adequacy of the existing data base will also be evaluated as part of this task.

6.2.6 Task 5: Exposure Assessment and Pathways Model

This task will identify the exposure or migration pathways of the contaminants, taking into account environmental fate and transport through both physical and biological means. Each pathway will be described in terms of the chemical(s) and media involved and the potential ecological receptors. The exposure assessment process will include the following three subtasks:

- Identify exposure pathways
- Determine exposure points and concentrations
- Estimate chemical intake for receptors

Each of these subtasks is described below.

6.2.6.1 Exposure Pathways

The purpose of this subtask is to qualitatively identify the actual or potential pathways by which various biological receptors at or near OU1 might be exposed to site-related chemicals or radionuclides. The exposure pathway analysis will address the following four elements:

- A chemical/radionuclide source and mechanism of release to the environment
- An environmental transport medium (e.g., soil, water, air) for the released chemical/radionuclide
- A point of potential biological contact with the contaminated medium
- A biological uptake mechanism at the point of exposure

All four elements must be present for an exposure pathway to be complete and for exposure to occur. Exposure pathways will be evaluated and modeled, where possible, using the pathways approach (Reagan and Fordham 1991; Thomann 1981).

The pathways approach uses a bioaccumulation model of contaminant transfer through a food web. The model links contamination in soil and water to contamination in biota. The pathways model approach blends standard environmental assessment methods with ecological and toxicological modelling to produce an integrated procedure to selecting indicator species and conducting an investigation of ecosystem effects resulting from contamination in soil and water. Where possible, uncertainty in the model is reduced by direct sampling (i.e., tissue analyses).

Toxicity tests, such as those proposed for Task 3, can also be used to conduct a direct effects-related investigation. Additional toxicity tests may be designed based on the pathways model results.

6.2.6.2 Determination of Exposure Points and Concentrations

The identified exposure points are those locations where key ecological receptor species may contact the contaminants of concern. Potential for exposure depends on characteristics of the contaminant, the organism, and the environment. Determination of exposure points entails an analysis of key receptor species, locations, and food habits in relation to potential contaminant exposure both through direct contaminant accumulation or deposition from the abiotic environment and through indirect bioaccumulation. The exposure assessment for OU1 will provide information on the following:

- What organisms are actually or potentially exposed to contaminants from OU1
- What the significant routes of exposure are
- What amounts of each contaminant organisms are actually or potentially exposed to
- Duration of exposure

- Frequency of exposure
- Seasonal and climatic variations in conditions which are likely to affect exposure
- Site-specific geophysical, physical, and chemical conditions affecting exposure

A determination of the nature and extent of contamination in the abiotic media (air, soils, surface water, and groundwater) is presented in the Phase III RFI/RI Work Plan for the 881 Hillside area (EG&G 1990b). Phase III data, where available and validated, will be summarized and used to characterize source areas and release characteristics at the site. The exact exposure points can be expected to vary depending on both the contaminant and the key receptor species under consideration.

Concentrations of chemicals that are likely to have the greatest impact (based on concentration in the environment, toxicity values, and biological uptake) will be determined by actual environmental media sampling for each exposure point or by environmental fate and transport modeling. Fate, transport, and endpoint contamination levels in abiotic media may be modeled where necessary using environmental multi-media risk assessment models. Such models can provide the potential maximum concentrations of chemicals at the exposure points by which to evaluate the "worst-case" scenario.

6.2.6.3 Estimation of Chemical Intake by Key Receptor Species

This step includes an evaluation of key receptor species' contaminant uptake by direct routes (i.e., inhalation, ingestion, dermal contact) and indirect routes (bioconcentration, bioaccumulation, biomagnification). The amounts of chemical and radiological uptake will be estimated using appropriate conservative assumptions, site-specific analytical data on contaminant concentrations in abiotic and biotic media, and forthcoming guidance from EPA's Wildlife Exposure Factors Handbook (to be published in 1991). The pathways analysis model (Reagan and Fordham 1991; Thomann 1981) will be used to establish relationships between concentrations of a chemical in different media with concentrations known to cause adverse effects.

Direct measurement of contaminant uptake through tissue analyses will be conducted during Task 9 of the environmental evaluation. Such site-specific data and field observations will be used to reduce uncertainty in the pathways model and strengthen interpretation of the overall study.

6.2.7 Task 6: Contamination Characterization

Contamination characterization entails the integration of abiotic exposure concentrations and reasonable worst-case assumptions with the information developed during the exposure and toxicity assessments to characterize current and potential adverse biological effects (e.g., death, diminished reproductive success, reduced population levels, etc.) posed by OU1 contamination. The potential impacts from all exposure routes (inhalation, ingestion, and dermal contact) and all media (air, soil, groundwater, and

surface water/ sediment) will be included in this evaluation as appropriate according to EPA guidance (U.S. EPA 1989b).

Characterization of adverse effects on receptor species and their populations is generally more qualitative in nature than characterizing human risks. This is because the toxicological effects of most chemicals have not been well documented for most species. Criteria or toxicological benchmarks that are usable and applicable for the evaluation of ecological effects are generally limited. EPA AWQC and Maximum Allowable Tissue Concentrations (MATC) are the most readily available criteria. Criteria found in federal and Colorado state laws and regulations pertaining to the preservation and protection of natural resources can also be used. Criteria may also be derived from information developed for use under other environmental statutes, such as the Toxic Substances Control Act or the Federal Insecticide, Fungicide and Rodenticide Act. An attempt will be made to consider the adverse effects of chemicals on populations and habitats rather than on individual members of a species according to EPA guidance (1989b, 1989a). Where specific information is available in the published literature, a more quantitative evaluation of effects will be made using the site-specific pathways model. This approach is in agreement with EPA guidance (U.S. EPA 1989b).

6.2.8 Task 7: Uncertainty Analysis

The process of assessing ecological effects is one of estimation under conditions of uncertainty. Understanding the effects of environmental stresses resulting from contamination on real populations depends on complex abiotic and biotic processes that cannot be reproduced in the laboratory. To address uncertainties, the OU1 environmental evaluation will present each conclusion, along with the issues that support and fail to support the conclusion, and the uncertainty accompanying the conclusion. Factors that limit or prevent development of definitive conclusions will also be discussed. In summarizing the assessment data, the following sources of uncertainty and limitations will be specified:

- Variance estimates for all statistics
- Assumptions and the range of conditions underlying use of statistics and models
- Narrative explanations of other sources of potential error

Validation and calibration of the pathways model will also be used where practicable.

6.2.9 Task 8: Planning

Task 8 will include planning for tissue analysis studies and any additional ecotoxicological studies (e.g., reproductive success, enzyme analyses, microbial respiration) needed to assess adverse effects from the contaminants of concern on key receptors. Initial designing for the Task 9 ecotoxicological field

investigations will begin after contaminants of concern and key receptors have been selected in Task 2. Species to be sampled for tissue analyses will be designated to the earliest extent possible in order to avoid a duplication of the Task 3 sampling effort.

The need for measuring additional ecotoxicological endpoints in Task 9 will be evaluated based on the pathways analyses and published information on direct toxic effects. Selection of field methodologies will be based on a review of available scientific literature providing quantitative data for the species of concern or similar test species. Analysis of population, habitat, or ecosystem changes will be based on species or habitats that represent broad components of the ecosystem or are especially sensitive to the contaminants. In order to select methodologies for the ecotoxicological field sampling program, the biological response under consideration and the proposed methodology should satisfy program DQOs as well as the following more specific criteria:

- The biological response is a well-defined, easily identifiable, and documented response to the designated contaminant(s) of concern (i.e., methodology and measurement endpoint are appropriate to the exposure pathway).

- Exposure to the contaminant is known to cause the biological response in laboratory experiments or experiments with free-ranging organisms.

- Methodology is capable of demonstrating a measurable biological response distinguishable from other environmental factors such as weather or physical site disturbance.

- The biological response can be measured using a published standardized laboratory or field testing methodology.

- The biological response measurement is practical to perform and produces scientifically valid results (e.g., sample size is large enough to have useful power and small Type I error).

Tissue studies to document site-specific contamination will be conducted in Task 9 for both aquatic and terrestrial systems. Tissue analyses will be conducted on selected species from OU1 and reference areas (if necessary) to document current levels of specific target analytes. Information from the Task 2 data evaluation and Task 3 field survey will determine the species and contaminants to be tested and the methods to be used. Selection of the target analytes, species, and tissues will depend on an initial determination as to which contaminants are likely to adversely impact biota and which contaminants are likely to be present in concentrations sufficient for detection.

Acute and chronic aquatic toxicity tests using fathead minnows and Ceriodaphnia spp. are proposed for Task 3 (see Subsection 6.3.5). These simple screening tests will provide an initial determination of the toxicity of potentially complex chemical mixtures in Woman Creek, the South Interceptor Ditch, and Pond C-2. If toxicity is observed in either the acute or chronic tests at any one station, then a supplemental toxicity testing program in conjunction with physical and chemical analyses of the water and sediment may be designed for that location to determine the potential extent of the toxicant(s).

Toxicity testing methods are available for terrestrial ecosystems using microbes, earthworms, crickets, and grasshoppers (U.S. EPA 1989b). The need for such tests will be evaluated based on the above criteria as part of this planning process.

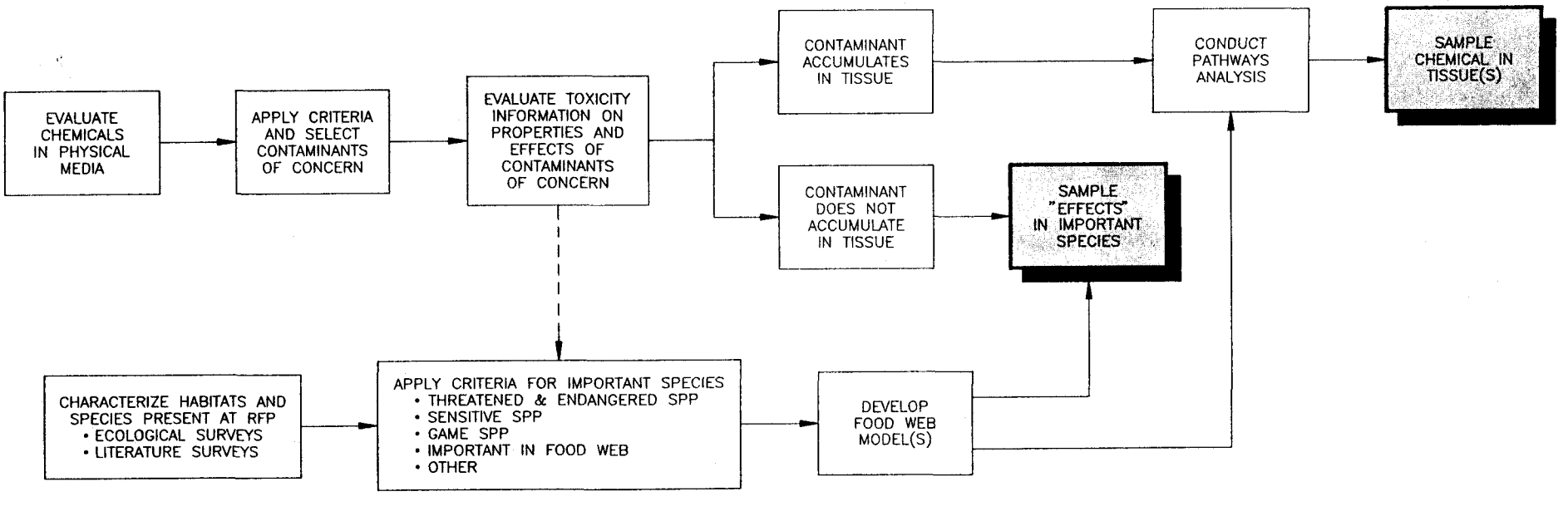
Prior to conducting Task 9 studies, the field sampling plan will be refined to address the proposed methodologies. More specific DQOs will be formulated based on the proposed methodologies and will address the following:

- The number and types of analyses to be run
- The species, locations, and tissues to be sampled
- The number of samples to be taken
- The detection limits for contaminants
- The acceptable margin of error in analyzing results

6.2.10 Task 9: Ecotoxicological Field Investigations

Tissue analyses will comprise most of the Task 9 ecotoxicological field investigation. Because individuals and species accumulate contaminants differentially in their tissues depending on the exposure route and form of the contaminants, environmental concentrations and general uptake rates will not necessarily predict biotic concentrations or adverse effects. Tissue analyses will be conducted to measure the total concentration of specific chemical compounds in key receptor species. By comparing tissue analysis results to toxicological benchmark concentrations (e.g., LC50 or MATC values), the potential for adverse effects in a population can be characterized. Analysis of tissue contaminant concentrations will also provide data to confirm the predicted relationship, if any, between environmental concentrations and the amount of contaminants accumulated in receptor species.

Selection of the species and specific tissues for analysis will be based on a preliminary evaluation of site-specific food webs, potential contaminant transport pathways, and potential for bioaccumulation, bioconcentration, and biomagnification. The decision process for conducting tissue analyses is presented in Figure 6-3. Tissue sampling will only be conducted for those contaminants of concern which bioaccumulate in tissue. Whole bodies or specific tissues will be analyzed depending on which



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

DECISION PROCESS FOR CHEMICAL SAMPLING OF TISSUES

FIGURE 6-3 MAY 1991

2506E001

portion is consumed by higher trophic level organisms. Suitability of the species for sampling and sampling size requirements will largely determine the species to be selected for tissue analysis.

To the extent possible, tissue samples will be collected simultaneously with environmental media samples (see Section 5.0 of the RFI/RI Work Plan, EG&G 1990b). This will allow for a determination of site-specific BCFs. These BCFs will be incorporated into the final exposure assessment and will be used to calibrate/validate the pathways model. Where BCFs cannot be determined, published or predicted BCF values will be used in the pathways model to assess potential impacts.

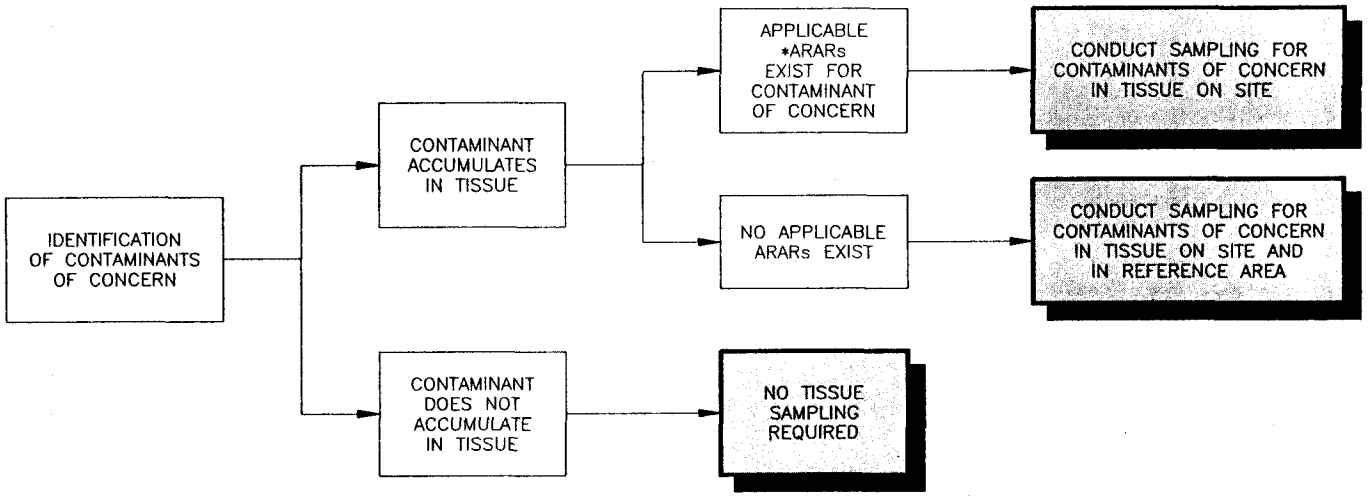
For contaminants of concern which bioaccumulate, the acceptable concentration (i.e., ARAR) in the physical environment (e.g., water) may be below reliable detection limits measurable by direct methods. For example, the chronic AWQC for protection of aquatic life for DDT is 1.9 nanograms per liter, while the detection level using gas chromatography is 0.1 micrograms per liter. In these instances, indicator species would be sampled as indirect indicators of contaminant concentrations in the physical media that bioaccumulate.

Where ARARs (i.e., acceptable levels in receptor species or next lowest prey species) are established, tissue sampling need only be conducted on site and not in the reference areas. Where no applicable ARARs exist, sampling for contaminants of concern would be conducted both on site and in appropriate reference area(s). The decision process on the use of reference areas for sampling contaminants in tissues is shown in Figure 6-4. Statistical tests will be used in the measurement of the contaminant-specific biological response in samples from OU1 and the reference areas. Use of statistical tests will be consistent with DQOs and quality assurance provisions of the Quality Assurance Project Plan (QAPjP).

Additional ecotoxicological studies or toxicity tests may include in-situ (in-field) and/or laboratory toxicity tests. In-situ methods usually involve exposing animals in the field to existing aquatic or soil conditions. Laboratory toxicity tests can be used to evaluate the lethal or sublethal effects of chemicals as they occur in environmental media. Both approaches can be used to test for toxicity of mixtures as they actually occur in the environment. Selection of a particular methodology is generally based on the capability of the method to demonstrate a measurable biological response to the selected contaminant(s) of concern in addition to those specific criteria presented in Subsection 6.2.9.

6.2.11 Task 10: Environmental Evaluation Report

Task 10 will include the summary of information and production of an Environmental Evaluation Report as part of the RFI/FI Report. The Environmental Evaluation Report will be prepared in a clear and



* ARARs MAY NOT BE APPLICABLE IF THEY ARE BASED ON SPECIES THAT DO NOT EXIST ON SITE (e.g., TROUT), ARE BASED ON BIOTA PATHWAYS TO HUMANS, OR IF THEY ARE BELOW BACKGROUND FOR THE REGION (e.g., SOME METALS).

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

DECISION PROCESS ON USE OF REFERENCE AREAS FOR CONTAMINANTS IN TISSUES

FIGURE 6-4 MAY 1991

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concise manner to present study results and interpretation. Relevant data from the environmental evaluation, in addition to relevant Phase III RFI/RI data, will be integrated and evaluated in the characterization of potential environmental impacts. The following topics will be covered in the report:

- Objectives
- Scope of Investigation
- Site Description
- Contaminants of Concern and Key Receptor Species
- Contaminant Sources and Releases
- Exposure Characterization
- Contamination (Impact) Characterization
- Remediation Criteria
- Conclusions and Limitations

A proposed, detailed outline of the report is shown in following Table 6-11.

Remediation Criteria

The primary element used in the assessment of environmental effects or risk is a set of environmental criteria to which measured and or predicted concentrations of hazardous constituents in abiotic media are compared. Where these criteria are exceeded, adverse effects are likely to occur. Where water quality or other available federal or state criteria are available for comparison to concentrations of contaminants, they are generally used (see Section 6.2.7) (U.S.EPA, 1989b). Remediation criteria can also be developed from other environmental statutes, such as the Toxic Substances Control Act or the Federal Insecticide, Fungicide and Rodenticide Act, or through the conduct of an environmental risk assessment such as outlined in this work plan.

Remediation criteria protective of biota are not available for contaminants in soils, or for many of the contaminants that occur in aquatic ecosystems at hazardous waste sites. Remediation criteria protective of site-specific plants and animals for the contaminants of concern can be developed in this environmental evaluation based on ecological effects criteria and detailed food-web analyses using a calibrated/validated pathways model. Ecological effects criteria are determined by tracing the biomagnification of contaminant residues from organisms at the top of the food web back through intermediate trophic levels to the abiotic environment. The "no effects" criteria levels for abiotic media are then derived from contaminant concentrations known to produce sublethal effects in the most sensitive (usually highest trophic level) organisms. Development of ecological effects criteria for OU1

TABLE 6-11
PROPOSED ENVIRONMENTAL EVALUATION REPORT OUTLINE
FOR 881 HILLSIDE

EXECUTIVE SUMMARY

1.0 INTRODUCTION

- 1.1 OBJECTIVES
- 1.2 SITE HISTORY
- 1.3 SCOPE OF EVALUATION

2.0 SITE DESCRIPTION

- 2.1 PHYSICAL ENVIRONMENT
  - 2.1.1 Air Quality/Meteorology
  - 2.1.2 Soils
  - 2.1.3 Surface Water
  - 2.1.4 Groundwater
- 2.2 BIOTIC COMMUNITY
  - 2.2.1 Freshwater Community
  - 2.2.2 Terrestrial Community
  - 2.2.3 Protected/Important Species and Habitats

3.0 CONTAMINANT SOURCES AND RELEASES

- 3.1 SOURCES
- 3.2 RELEASES

4.0 CONTAMINANTS OF CONCERN

- 4.1 CRITERIA DEVELOPMENT FOR SELECTION OF CONTAMINANTS OF CONCERN
- 4.2 DEFINITION OF CONTAMINANTS

5.0 TOXICITY ASSESSMENT

- 5.1 TOXICITY ASSESSMENTS OF CONTAMINANTS OF CONCERN
- 5.2 CONTAMINANT EFFECTS
  - 5.2.1 Terrestrial Ecosystems
  - 5.2.2 Aquatic Ecosystems

6.0 EXPOSURE ASSESSMENT

- 6.1 CONTAMINANT PATHWAYS AND ACCEPTABLE CRITERIA DEVELOPMENT
  - 6.1.1 General Methodology for Pathway Analysis
  - 6.1.2 Selection of Key Receptor Species

TABLE 6-11
PROPOSED ENVIRONMENTAL EVALUATION REPORT OUTLINE
FOR 881 HILLSIDE
(Concluded)

6.2 EXPOSURE POINT IDENTIFICATION

6.2.1 Soil
6.2.2 Water
6.2.3 Vegetation

6.3 CHEMICAL FATE AND TRANSPORT
6.4 EXPOSURE POINT CONCENTRATIONS

6.4.1 Soil and Sediment Concentrations
6.4.2 Surface Water Concentrations
6.4.3 Groundwater Concentrations
6.4.4 Vegetation Concentrations

6.5 EXPOSURE PATHWAYS

6.5.1 Terrestrial Pathway
6.5.2 Freshwater Pathway

7.0 CONTAMINATION CHARACTERIZATION

7.1 DEVELOPMENT OF ECOLOGICAL EFFECTS CRITERIA

7.1.1 Air Criteria
7.1.2 Soil and Sediment Criteria
7.1.3 Freshwater Criteria
7.1.4 Vegetation Criteria

7.2 EFFECTS CHARACTERIZATION

7.2.1 Terrestrial Pathway

7.2.1.1 Air
7.2.1.2 Soil
7.2.1.3 Vegetation

7.2.2 Freshwater Pathway

7.2.2.1 Air
7.2.2.2 Surface Runoff
7.2.2.3 Seeps and Springs

8.0 ASSUMPTIONS AND UNCERTAINTIES

9.0 RECOMMENDATIONS AND CONCLUSIONS

10.0 REFERENCES

will be based on results of the pathways model as well as available data which document potential adverse effects from contaminants of concern on key biological receptors. The process for establishing ecological criteria is shown in Figure 6-5. Determination of these criteria for OU1 will be coordinated with other RFI/RI studies and environmental evaluations.

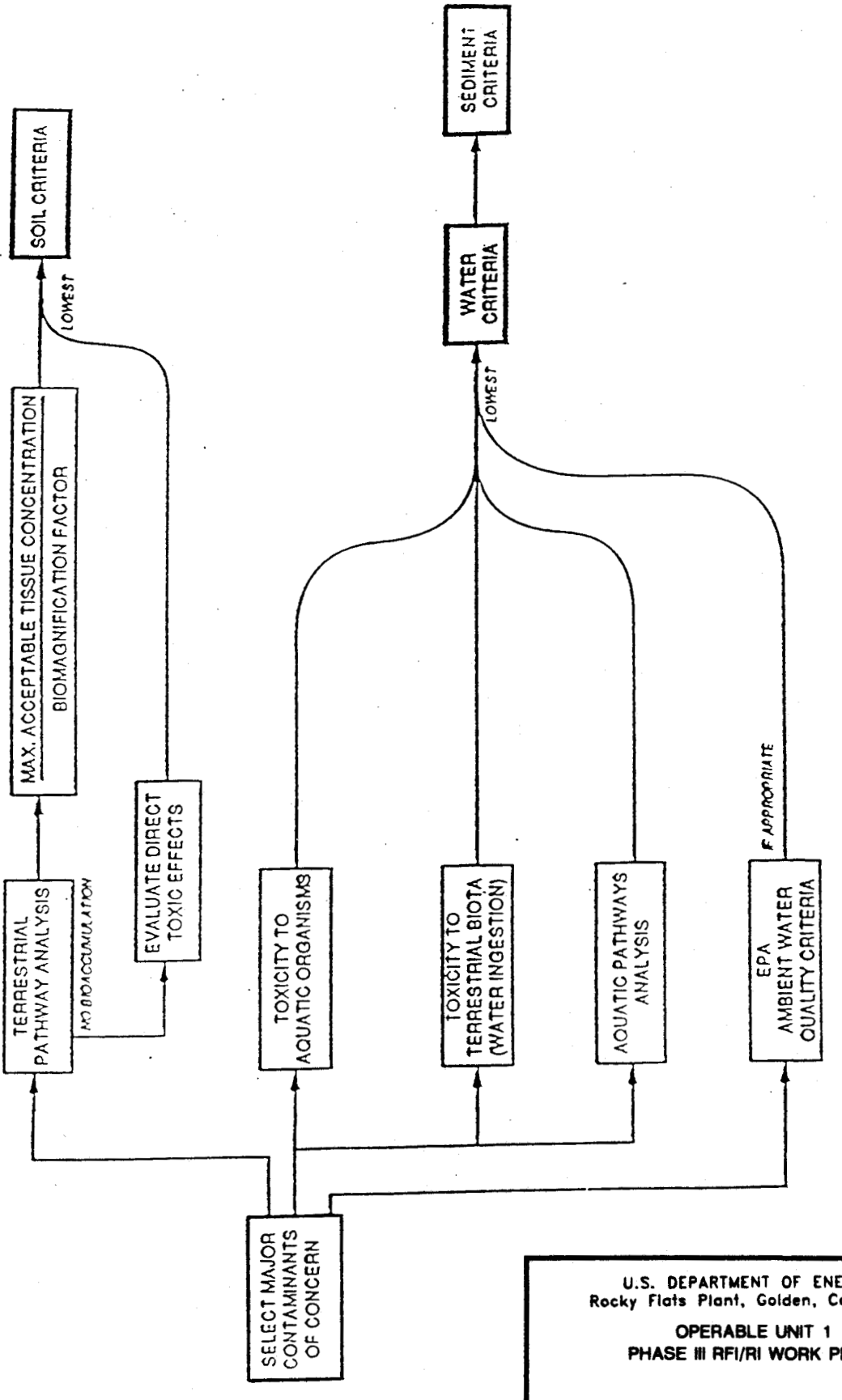
The acceptable (no-effects) criteria levels will be used in conjunction with ARARs to evaluate potential adverse effects on biota as appropriate for the environmental evaluation portion of the Phase III RFI/RI. This approach will be integrated with the Human Health Risk Assessment process and will assist in the development of potential remediation criteria.

6.3 FIELD SAMPLING PLAN

The OU1 Environmental Evaluation is planned in 10 tasks as described in Subsection 6.2. Field sampling activities will be conducted in Task 3 and Task 9 of the Environmental Evaluation. Task 3 will include brief field surveys, an ecological inventory of biota present at OU1, and initial aquatic toxicity testing. The field surveys and inventory will be conducted to obtain information on the occurrence, distribution, and general abundance of biota in OU1. Data obtained in the field inventory will be used to identify key receptor species, to develop a site-specific foodweb model, and to provide input to the pathways analysis and contamination assessment. Planning for the Task 9 tissue analysis program will begin in Task 2 so that samples collected in the Task 3 field inventory may be used wherever possible(i.e., where contaminants of concern have been defined and field sampling protocol have been developed). Final determination of the need for further ecotoxicological studies in Task 9 will be made in Task 8, Planning, after completion of the contamination assessment.

The following field sampling plan is provisional and will be periodically revised as appropriate. The Task 3 sampling plan is largely complete but may be altered in order to better coordinate with the surface water and soil sampling programs for OU1 or other operable units. The Task 9 field sampling plan will be designed in greater detail after contaminants of concern and key receptor species have been identified and a preliminary determination of food webs and contaminant source-receptor pathways has been developed. This information will allow determination as to which contaminants of concern are likely to be present in sufficient concentrations to be detected in biota and which biota are most practical and suitable for sampling.

SOPs for sampling biota as part of the Environmental Evaluation process at Rocky Flats are currently in publication. The SOPs will include discussion of purpose and scope, responsibilities and qualifications, references, equipment, and execution of protocols. Sampling procedures for the following organisms will be included in the forthcoming document:



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

OUTLINE OF THE METHODOLOGY FOR DETERMINING CRITERIA FOR MAJOR CONTAMINANTS OF CONCERN

SOURCE: REAGAN AND FORDHAM, 1991

FIGURE 6-5 MAY 1991

- Periphyton
- Benthic macroinvertebrates
- Plankton
- Fishes
- Large mammals
- Small mammals
- Birds
- Reptiles and amphibians
- Terrestrial arthropods
- Terrestrial vegetation
- Soil microbes

SOPs that are currently being developed in addition to the above include the following:

- Design of Field Sampling Plans
- Selection of Reference Areas
- Recording and Managing Data
- Preserving and Handling Samples
- Conducting Laboratory Studies
- Incorporating QA/QC

The preceding SOPS are referenced in the following OU1 Field Sampling Plan where appropriate.

6.3.1 Sampling Objectives

The Task 3 Ecological Field Investigation for OU1 has four broad objectives:

1. Conduct brief field surveys and an ecological inventory to describe the existing ecological setting in terms of habitats, vegetation, wildlife, and aquatic species. Conduct initial aquatic toxicity testing using Ceriodaphnia spp. and fathead minnows. Observe OU1 for obvious signs or zones of contamination or injury to biota and their habitats will be made. Accomplish ecological field inventory, through the use of established ecological field methodologies (e.g., Mueller-Dombois and Ellenberg 1974; Southwood 1978; Krebs 1989).

2. From the above data, identify key food web species which represent the major flow of energy and nutrients and thus the major pathways for contaminant transfer from physical environmental media to higher trophic-level ecological receptors.

3. Identify the presence or absence of protected or other important species and habitats.

4. Provide site-specific information for determining objectives, measurement endpoints and methodologies for Task 9 field/laboratory contamination studies.

Data from the field survey, inventory, and aquatic toxicity tests will be summarized, tabulated and accompanied with a narrative description of the following data types:

- Species Present (Diversity)
- Habitat Descriptions/Mapping Units (Clark et al. 1980)
- Soil Descriptions/Classifications (part of RFI effort)
- Critical/Protected Habitats
- Protected Species
- Terrestrial and Aquatic Food Webs
- Potential Exposure Pathways
- Abundance of Key Species
- Vegetation Cover
- Vegetation Frequency and Density (shrubs/trees)
- Vegetation Importance (community dominance) Values
- Aquatic Toxicity Test Results

Appropriate statistical tests will be used to analyze the data so that precision and accuracy of the results can be presented at a stated level of confidence. Depending on the data types being analyzed, within-and-between station differences, within-and-between season differences, and within-and-between species differences will be presented. Means, variances, standard errors, analyses of variance, regression, and correlation coefficients will be computed as appropriate. Where sample sizes are insufficient to detect differences, only descriptive statistics will be prepared.

6.3.2 Sample Location and Frequency

Both Task 3 and Task 9 field sampling activities for OU1 will be located and timed to the extent possible to coincide with collection of other media samples (soils, surface water, and groundwater) as well as sampling activities at other operable units. This integrated sampling approach is consistent with EPA guidance and will provide a synoptic view of potential contaminants in all relevant media at one time.

The field sampling plan for Task 3 is based on the assumption that brief field surveys will be conducted in the spring, summer, fall, and winter and that the ecological field sampling program will take place within the May-June and July-August timeframes. Aquatic toxicity testing will take place in May-June

(high flow) and September-October (low flow). Information from the initial surveys and field inventory may be used to modify sampling parameters for later field investigations.

Sampling locations are largely located at or downgradient from areas of known or suspected contamination. Sampling locations were selected to coincide with sampling efforts in abiotic media and to characterize the biotic communities that are present. The intent of the selected locations was not to test specific hypotheses regarding the effects of contamination, but to characterize the ecological communities that are present and provide site-specific input to the pathways model.

6.3.2.1 Locations for Vegetative Sampling

Vegetation sampling for phytosociological data will be performed at OU1, and along the South Interceptor Ditch and Woman Creek, south and east of the 881 Hillside area. A systematic walk-through of these areas will be conducted in the spring, summer, and fall to observe species composition.

A stratified randomization procedure will be utilized to identify sampling locations for the quantitative vegetative description portion of the field inventory. The basis for selecting a random procedure of vegetation transect/plot location is to obtain as unbiased an estimator as possible of true population parameters for herbaceous cover and shrub/tree density and frequency. Stratification is required because several distinct vegetation types appear to be present in the study area, including prairie grassland, marsh, streambank vegetation, well-vegetated disturbed areas, and sparsely vegetated disturbed areas.

The basis for stratification will be a vegetation type map, to be prepared based on the 1975 University of Colorado vegetation map of Rocky Flats and the Clark et al. (1980) report, updated by visual observations during the field surveys. This map will address the 881 Hillside area.

Transects for the quantitative community surveys will be located near soil sampling sites (see Subsection 5.1.1 in RFI/RI Work Plan, EG&G 1990b) wherever possible. From each soil sampling point, the centerpoint of a vegetation transect will be selected based on a random distance (to 10 m) and random direction, using random numbers tables. Transect locations will be selected until an adequate number has been selected for each major vegetation type at each IHSS. Locations will be discarded under several conditions: where the selected location is in a vegetation type for which an adequate number of transects has already been selected (for each IHSS); where the vegetation is not homogeneous (i.e., located in more than one type or across an ecotone); and where the transect would be located in buildings or paved areas. A similar process will be used for transects along Woman Creek and the South Interceptor Ditch, where the sample locations will be located in the general area of the surface-water/sediment sampling points. Since vegetation types associated with these features tend to be

linear, the randomization process may require limits on direction. Multiple transects will be located near (within 50 meters of) each surface water/sediment sampling point to provide an adequate sample size.

6.3.2.2 Locations for Periphyton, Macrobenthos and Fish Sampling

Periphyton, macrobenthos, and fish samples will be collected at the following surface water sampling locations: SW-31, SW-32, SW-46, SW-67, SW-70, and Pond C-2 (Figure 6-6). Should the organisms or proper habitat be absent at a particular location, then the nearest location downstream with suitable habitat will be sampled and located on a map. Sampling at OU1 will be coordinated with OU1 surface water and sediment sampling activities as well with OU5 and OU2 sampling programs. Both sediment and surface water quality data will be collected at the same locations and time as the aquatic biota sampling. Sampling locations may be altered to ensure these efforts are coordinated. Sampling locations for aquatic biota may also be altered depending on DQOs or required sample size.

6.3.2.3 Locations for Wildlife Sampling

A terrestrial wildlife inventory will be conducted within the 881 Hillside area, and along the South Interceptor Ditch, and Woman Creek south and east of 881 Hillside. Small mammal sampling will be conducted, to the extent possible, at the vegetative sampling locations. Searches for reptiles will be conducted in appropriate habitats in OU1.

6.3.2.4 Locations for Initial Toxicity Testing

Locations for initial aquatic toxicity testing will be mostly the same as those for periphyton, macrobenthos, and fish sampling: SW-31, SW-32, SW-46, SW-67, SW-70, and Pond C-2 (Figure 6-6). Toxicity testing activities for OU1 will be coordinated with toxicity testing activities proposed for OU2 and OU5 as part of the implementation of the field sampling effort.

6.3.2.5 Tissue Sampling Locations

Locations for the collection of tissue samples (terrestrial vegetation, periphyton, benthos, macrobenthos, fish) will be the same as those for terrestrial and aquatic sampling. An initial identification of species for tissue sampling will be made in Task 2. Additional sampling requirements will be determined during the contamination assessment (Tasks 4 through 7) and contaminant data from surface water, soil and sediment sampling. The intent is to collect tissue samples where existing abiotic media sampling has indicated significant contamination to occur. Development of the OU1 tissue sampling program will be coordinated with OU5 and OU2 programs.

6.3.2.6 Sample Frequency

Brief field surveys will be conducted during 1-week periods in the spring, summer, fall, and winter. Special note of transitory species, migratory species, and seasonal breeding habits will be made during these multi-season surveys.

Field inventory sampling will occur during the May-June and July-August timeframes. Samples collected during the inventory will be saved and used in the tissue analysis studies where sampling and analysis protocol have been established.

Initial toxicity tests will also be conducted during May-June (high flow) and September-October (low flow). Two acute and two chronic tests will be conducted within 1 to 2 weeks of each other during each season. If toxicity is observed in either acute or chronic tests at any one station, then a supplemental program will be designed for that location to determine if the toxicity is consistent and to determine the potential extent of the toxicant.

6.3.3 Reference Areas

Tissue analysis studies may require the sampling of contaminated and control areas in order to establish a relationship between contaminated conditions and background conditions in areas not exposed to Rocky Flats Plant contamination. Selection of reference areas may be based on criteria developed in the Task 1 preliminary planning process and may be coordinated with similar efforts at other operable units. Potential selection criteria include species to be sampled or similarity to OU1 in terms of topography, aspect, soils, vegetation, range type, and land use history. Reference areas should be upwind from prevailing air flow patterns through Rocky Flats Plant and upstream from drainage off Rocky Flats Plant.

SOPs for sampling biota as part of the environmental evaluation process at Rocky Flats are currently in publication. Additional aquatic reference areas ideally should be located in Rock Creek. A site visit will be made of the proposed aquatic sampling locations for OU1, OU2, and OU5. Habitat characteristics will be noted if not previously recorded in ongoing Rocky Flats Plant studies (depth, flow, substrate type, pool/riffle, aquatic/streamside vegetation, etc.). This process will be repeated at potential reference sites.

Reference areas would be selected only after criteria, data quality objectives, and measurement endpoints are identified. The process for selecting reference areas will be initiated in Task 1.

6.3.4 Field Survey and Inventory Sampling Methods

Sampling methods for periphyton, benthic macroinvertebrates, fishes, mammals, birds, reptiles, and amphibians, terrestrial arthropods, and terrestrial vegetation are detailed in the Ecology SOPs. The SOPs include several standardized forms to be used when sampling biota. Site Description Form 5.0D will be used for sampling terrestrial biota; stream and pond habitat description forms (Forms 5.0A and 5.0B) will be completed at each of the aquatic sampling locations. Chain-of-custody field sample forms will be completed where samples are collected for laboratory analysis or voucher specimens. Additional forms to be completed are specified in the following subsections.

6.3.4.1 Vegetation

Both qualitative and quantitative methods will be used to characterize the terrestrial and wetland vegetation at OU1. Qualitative surveys using a relevé analysis (see Ecology SOPs) will be conducted in the spring, summer, and fall to record the floristic composition of the plant communities present. These qualitative surveys will include a systematic walk-through of the 881 Hillside area, the South Interceptor Ditch, and the Woman Creek area. The following data will be recorded on all vegetation species encountered:

- Scientific name
- Common name
- Life form
- Vegetative stage at the time
- Qualitative statement on condition
- Qualitative statement on abundance (relevé analysis - see Ecology SOPs)

Quantitative procedures will be used to collect structural and compositional data. Point-intercept transects will be used to collect data on species cover. Data will be recorded on Form 5.10B, Point-Intercept Data Form. Belt transects will be used in conjunction with the point-intercept transects to collect data on shrub cover and density. Trunk diameter, height, canopy diameter, and species will be recorded for any trees within the belt transect or within any IHSS. Shrub and tree data will be recorded on Form 5.10C, Belt Transect Data Form. Production data (standing biomass) will be collected from 1/4- to 1-m^2 quadrants at the same locations as the transects. Different quadrant sizes may be used depending on vegetation type (e.g., a 1/4-m^2 quadrant may be used on dense streambank vegetation). Production data will be recorded on Form 5.10D.

Each plot or 10-meter transect will be considered as an observation in calculating the mean and variance. Sample adequacy will be determined for total herbaceous cover and total fresh weight biomass using Cochran's formula (1977):

$$N = \frac{(t^2)(s^2)}{[(x)(d)]^2}$$

where: N = the minimum number of samples needed
t = t distribution value for a given level of confidence
s^2 = the variance estimate
x = the mean of the sample
d = the level of accuracy desired

6.3.4.2 Terrestrial Wildlife and Invertebrates

The Task 3 survey is planned to note the presence or absence of terrestrial/wetland species and to make note of their food habits. The survey procedure will include a systematic walk-through of the 881 Hillside area, South Interceptor Ditch, and Woman Creek to record ecological features. Field data will be recorded on the standardized Qualitative Survey/Relative Abundance Data Form 5.0C for large mammals, small mammals, birds, reptiles and amphibians, and terrestrial arthropods. Opportunistic observations of bird and raptor nests, large mammal pellets, and mammal burrow/dens will be recorded on the appropriate forms. Vocalization surveys for birds and anurans will also use the appropriate forms. Data to be recorded include:

- Species encountered/ observed
- Scientific name
- Common name
- Qualitative statement on:
  - Condition
  - Abundance
  - Habitat requirements
  - Predator/prey species/food habits
  - Regulatory status (to be determined prior to field sampling)
- Species presence will be determined by:
  - Visual observation
  - Vocalization
  - Burrow/den
  - Nest
  - Droppings/scat

Quantitative information on wildlife populations will be obtained in the Task 3 field inventory. Inventory sampling will include the following procedures, which are detailed in the SOPs:

- Live trapping of small mammals on the hillsides and along the South Interceptor Ditch and Woman Creek. Data to be recorded include:

  - Scientific name/common name
  - Sex
  - Reproductive condition
  - Weight
  - Life history stage

- Reptile occurrence will be recorded along the same transects used for small mammal trapping in addition to habitat searches. Data to be recorded include:

  - Species encountered
  - Activity
  - Habitat
  - Qualitative statement on abundance

- Medium- and larger-sized mammals will be counted by recording all species along a systematic walk-through of the 881 Hillside area, the South Interceptor Ditch, and Woman Creek. The counting will occur during the small mammal transect trapping. Species encountered and activity will be recorded.

- Foliage invertebrates will be collected by sweep net and beating. Where conditions permit, foliage invertebrate and arthropod sampling may be conducted using a D-vac suction sampler in place of sweep netting (see Ecology SOPs). Data to be recorded will include:

  - Host plant
  - Herbivore
  - Position in food web

6.3.4.3 Periphyton

Sampling to characterize periphyton communities will occur at the selected locations along Woman Creek, the South Interceptor Ditch, and Pond C-2 (see SOP). Triplicate samples will be taken on a

transect upstream and within 10 meters of the designated sampling location. Data to be collected include:

- Scientific name
- Algal density (cell counts of each taxon)
- Biomass (chlorophyll-a and phaeophytin-a concentrations)

Field data will be recorded on the Periphyton Field Sample Form 5.1A (see SOP 5-1). Data from quantitative sampling will be used to determine species diversity and standing crop (biomass). All analyses will be completed within five days of the collection of the slides from the field (U.S. EPA 1987b).

6.3.4.4 Macrobenthos

Benthic invertebrates are the most common fauna used in ecological assessments of contaminant releases and are defined as the invertebrates retained by screens of mesh size greater than 0.2 mm. Macrobenthos will be sampled at the aquatic sampling locations shown in Figure 6-6 using the procedures described in the SOPs. Triplicate samples will be taken on a transect upstream and within 10 meters of the designated sampling locations. Data to be collected include:

- Scientific name (generally to genus)
- Number of individuals in each taxon

Field data will be recorded on the benthic macroinvertebrate field sample form 5.2A. Data from quantitative samples will be used to determine macroinvertebrate density (standing crop), taxa richness, and taxa diversity.

6.3.4.5 Fish

Fish will be collected in 10- to 25-meter-long collection areas using a backpack shocker or by seining blocked-off creek sections. In Pond C-2, fish will be sampled from a flat-bottom boat using an electroshocker. Data to be collected include:

- Scientific name
- Number of individuals in each taxon
- Length
- Weight

Scales will be collected to obtain data on age classes versus size, population structure, and survivorship. Field data will be recorded on the Fish Field Inventory form 5.4B (see SOP 5-4). Samples will be taken for laboratory identification/confirmation. Analyses will consist of compiling and summarizing the number, size, and weight of each species of fish captured at each sampling site. Graphic presentations may include fish length-frequency histograms and plots of catch-per-effort for each sampling area.

6.3.5 Initial Toxicity Tests

The initial toxicity testing program will be limited to aquatic organisms and will include standardized EPA acute and chronic tests with fathead minnows and Ceriodaphnia spp. Water samples will be cooled to 4°C and shipped to the laboratory conducting the toxicity tests within 12 to 24 hours. The toxicity tests will be initiated within 36 hours of the field collection time. The duration of the static renewal acute tests will be 48 hours for Ceriodaphnia spp. and 96 hours for fathead minnows. The test water will be renewed daily using dilution water from the sampling station. The static renewal chronic tests will last for 7 days for fathead minnows and until 60 percent of the Ceriodaphnia spp. in the control vessels have three broods. Quality control procedures will conform to the EPA requirements for NPDES toxicity testing currently being used at Rocky Flats and to the QAPjP.

6.3.6 Tissue Analysis Sampling Methods

The methodologies selected for tissue analysis studies will depend on the contaminants of concern and their anticipated effects on the selected key receptor species. Contaminants of concern and key receptor species will be determined as early as possible in Task 2. It is anticipated that some biota samples collected in the Task 3 field inventory can be used for tissue analysis. Standardized site protocol for preserving samples for tissue analyses will be followed in those instances where it is anticipated that tissue analyses will be conducted.

Analyses for metals and radionuclides in biota may call for a greater biomass of tissue than is available through standard collection methods. At least 80 grams of material (wet weight) is needed per sample for metals analysis, and 100 grams of material (dried and ashed) is needed for radionuclides. Obtaining this amount of sample may be impractical for some species of vegetation, periphyton, and macrobenthos. It is also not the intent of the sampling program to cause unnecessary disturbance or damage to the biota communities in order to collect sufficient samples. Sampling design will be adequate to ensure statistically valid results. DQOs for the tissue sampling program will be evaluated with respect to this determination prior to field collection activities.

Based on the literature reviewed and the information presented in this report, it is anticipated that most tissue samples will be analyzed for metals and very few samples, if any, may be analyzed for radionuclides. Tissue samples collected for contaminant analysis will be sent to a laboratory for specific

metals and radionuclide analyses as determined in the preliminary Task 1/Task 2 environmental evaluation. Analytical methods will follow SOPs.

Holding times, preservation methods, sample containers, and field and laboratory quality control sample numbers are contained in the QAPjP and shown in Table 6-12. Tissue sampling protocol for biota are not necessarily standardized and may vary depending upon the laboratory conducting the analyses. Specific sample preparation requirements will be reported in SOPs which are currently in development.

6.3.7 Sampling Equipment

Equipment for field sampling of biota are identified in the Volume V Ecology SOPs.

6.4 SCHEDULE

The following Figure 6-7 presents a proposed schedule for implementation of the OU1 environmental evaluation. The schedule follows the task approach presented in this environmental evaluation. While many of the tasks are sequential, most tasks will overlap in time. The months indicated in the table reflect the timeframe in which the activity will occur and not necessarily the amount of time necessary to complete the task. The schedule is provisional and likely to change depending on the Phase III OU1 RFI/RI activity schedule as well as schedules from other operable units.

TABLE 6-12

HOLDING TIMES, PRESERVATION METHODS, AND SAMPLE CONTAINERS FOR BIOTA SAMPLES

	Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size++
SAMPLES FOR METALS ANALYSES				
Terrestrial Vegetation				
- Metals Determined by ICP**	6 mos	Freeze & ship w/ dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Metals Determined by GFAA+	6 mos.	Freeze & ship w/ dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Hexavalent Chromium	24 hours	Freeze & ship w/ dry ice	Paper bag inserted into plastic bag and sealed	25 g
- Mercury	28 days	Freeze & ship w/ dry ice	Paper bag inserted into plastic bag and sealed	5 g
Periphyton, Benthic Macroinvertebrates, Fish				
- Metals Determined by ICP	6 mos.	Freeze & ship w/ dry ice	Plastic	25 g
- Metals Determined by GFAA	6 mos	Freeze & ship w/ dry ice	Plastic	25 g
- Hexavalent Chromium	24 hours	Freeze & ship w/ dry ice	Plastic	25 g
- Mercury	28 days	Freeze & ship w/ dry ice	Plastic	5 g

TABLE 6-12
HOLDING TIMES, PRESERVATION METHODS, AND SAMPLE CONTAINERS FOR BIOTA SAMPLES
(Concluded)

	Holding Time From Date Collected	Preservation Method	Container	Approximate Sample Size++
SAMPLES FOR RADIONUCLIDE ANALYSES				
Terrestrial Vegetation				
- Uranium-233, -234, -235, -238 Americium-241 Plutonium-239/240	6 mos	Freeze & ship w/ dry ice	Paper bag inserted into plastic bag and sealed	100 g
Periphyton, Benthic Macroinvertebrates, Fish				
- Uranium-233, -234, -245, -238 Americium-241 Plutonium-239/240	6 mos	Freeze & ship w/ dry ice	Plastic	100 g

**ICP = Inductively Coupled Argon Plasma Emission Spectroscopy. Metals to be determined include Ba, Cr, Cu, and Fe.

+GFAA = Graphite Furnace Atomic Absorption Spectroscopy. Metals to be determined include As, Cd, Li, Pg, Se, and Sr.

++ Sample size may vary with specific laboratory requirements.

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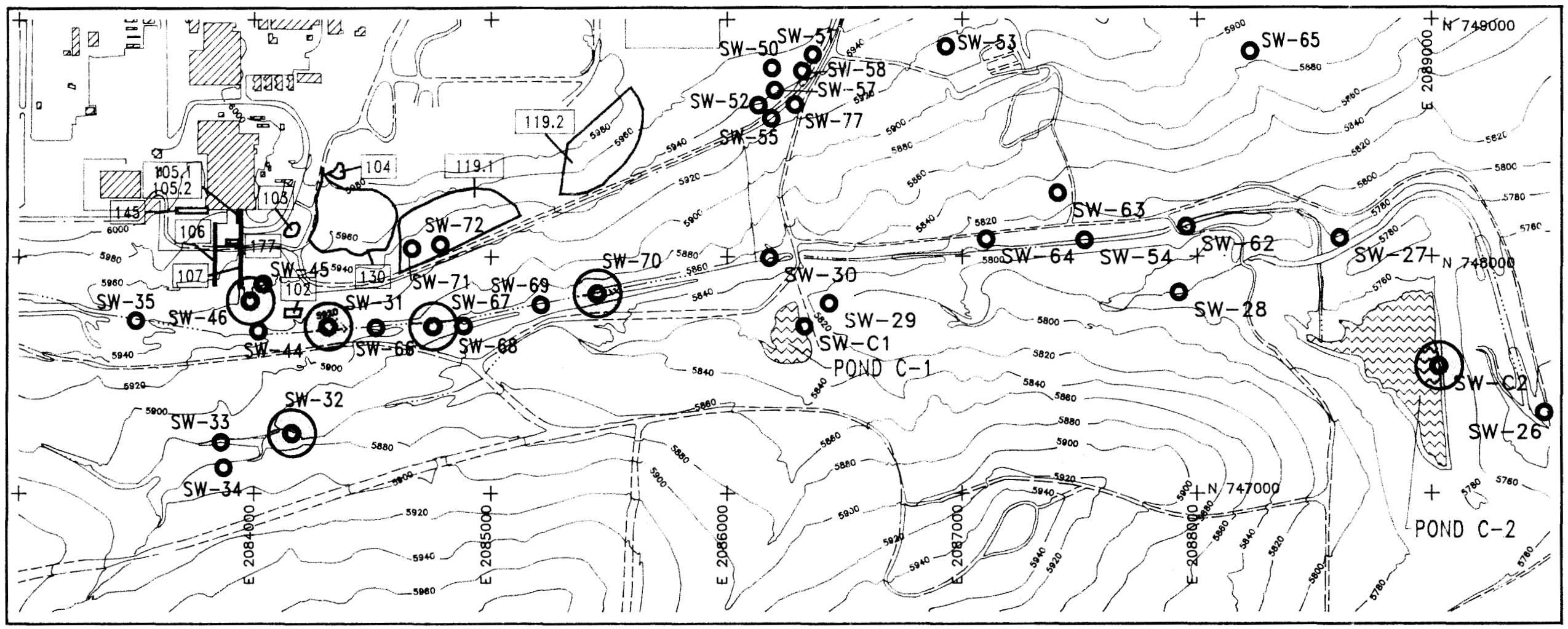

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) IN OPERABLE UNIT 1
- 177 — IHSS REFERENCE NUMBER
- SW-35 — SURFACE WATER MONITORING STATION
- ==== DIRT ROAD
- SAMPLING LOCATION FOR AQUATIC BIOTA[1]

[1] ALL PROPOSED LOCATIONS ARE APPROXIMATE

IHSS No. 102 – OIL SLUDGE PIT SITE
IHSS No. 103 – CHEMICAL BURIAL SITE
IHSS No. 104 – LIQUID DUMPING SITE
IHSS Nos. 105.1 & 105.2 – OUT-OF-SERVICE FUEL TANK SITES
IHSS No. 106 – OUTFALL SITE
IHSS No. 107 – HILLSIDE OIL LEAK SITE
IHSS Nos. 119.1 & 119.2 – MULTIPLE SOLVENT SPILL SITES
IHSS No. 130 – RADIOACTIVE SITE – 800 AREA #1
IHSS No. 145 – SANITARY WASTE LINE LEAK
IHSS No. 177 – BUILDING 885 DRUM STORAGE SITE

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OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES AND AQUATIC SAMPLING LOCATIONS

FIGURE 6-6 MAY 1991

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DESCRIPTION	MON 1	MON 2	MON 3	MON 4	MON 5	MON 6	MON 7	MON 8	MON 9	MON 10	MON 11	MON 12	MON 13	MON 14	MON 15	MON 16	MON 17	MON 18	MON 19	MON 20	MON 21
TASK 100 – PRELIMINARY PLANNING																					
110 DEFINE STUDY AREA																					
120 DETERMINE SCOPE																					
130 IDENTIFY DATA QUALITY OBJECTIVES																					
140 DEVELOP AND REACH CONSENSUS ON SITE-WIDE SELECTION CRITERIA FOR:																					
141 – CONTAMINANTS OF CONCERN																					
142 – KEY RECEPTOR SPECIES																					
143 – REFERENCE AREAS																					
144 – SAMPLING APPROACH/DESIGN																					
150 COORDINATE WITH HUMAN HEALTH RISK ASSESSMENT EFFORTS																					
160 COORDINATE WITH OTHER OU ENVIRONMENTAL EVALUATIONS																					
TASK 200 – DATA COLLECTION/EVALUATION/CONCEPTUAL MODEL DEVELOPMENT																					
210 SUMMARIZE EXISTING SAMPLING/ANALYSIS DATA																					
220 COLLECT INFORMATION FROM OTHER DOE CERCLA SITES																					
230 IDENTIFY RFI AND BACKGROUND INFORMATION DATA GAPS																					
240 DEVELOP PRELIMINARY ECOLOGICAL RISK ASSESSMENT																					
241 – IDENTIFY PRELIMINARY CONTAMINANTS OF CONCERN																					
242 – IDENTIFY POTENTIAL RECEPTOR SPECIES																					
243 – DEVELOP FOOD WEB MODEL																					
244 – IDENTIFY PRELIMINARY EXPOSURE PATHWAYS																					
245 – DEVELOP PRELIMINARY TOXICOLOGICAL ASSESSMENT																					
250 REVISE SAMPLING DESIGN																					
TASK 300 – ECOLOGICAL FIELD INVESTIGATION																					
310 CONDUCT ECOLOGICAL FIELD SURVEYS																					
311 – SPRING																					
312 – SUMMER																					
313 – FALL																					
314 – WINTER																					
320 CONDUCT INITIAL AQUATIC TOXICITY TESTS																					
330 COLLECT FOOD HABITS DATA																					
340 IDENTIFY POTENTIAL REFERENCE AREAS																					
TASK 400 – TOXICITY ASSESSMENT																					
410 COMPILE TOXICITY LITERATURE																					
420 ASSESS/QUANTIFY TOXICITY OF CONTAMINANTS OF CONCERN ON KEY RECEPTOR SPECIES																					
TASK 500 – EXPOSURE ASSESSMENT AND PATHWAYS MODEL																					
510 ANALYZE CONTAMINANT RELEASES																					
520 DEVELOP SOURCE-RECEPTOR PATHWAYS MODEL																					
530 IDENTIFY EXPOSED POPULATIONS																					
540 IDENTIFY AND QUANTIFY CHEMICAL INTAKES																					
550 EVALUATE PATHWAYS MODEL																					
TASK 600 – PRELIMINARY CONTAMINATION CHARACTERIZATION																					
610 DEVELOP PRELIMINARY DETERMINATION OF BIOTA CONTAMINATION																					
620 CHARACTERIZE POTENTIAL FOR EXPOSURE AND ADVERSE EFFECTS																					
630 EVALUATE RELEVANCE OF IMPACTS TO "NO ACTION" REMEDIAL SCENARIO																					
TASK 700 – UNCERTAINTY ANALYSIS																					
710 EVALUATE UNCERTAINTY																					
720 SUMMARIZE INFORMATION																					
730 IDENTIFY DATA NEEDS TO CALIBRATE/VALIDATE PATHWAYS MODEL																					
TASK 800 – PLANNING																					
810 REVISE FIELD SAMPLING PLAN																					
820 IDENTIFY ADDITIONAL DATA QUALITY OBJECTIVES																					
830 SELECT MEASUREMENT ENDPOINTS																					
831 – DECIDE ON CONTAMINANTS FOR ANALYSIS																					
832 – DECIDE ON TISSUES FOR ANALYSIS																					
TASK 900 – ECOTOXICOLOGICAL FIELD INVESTIGATIONS																					
910 CONDUCT TISSUE ANALYSES STUDIES																					
920 CONDUCT OTHER ECOTOXICOLOGICAL (EFFECTS) STUDIES																					
930 DATA VALIDATION																					
TASK 1000 – FINAL CONTAMINATION CHARACTERIZATION																					
1010 INCORPORATE SITE TOXICITY DATA INTO PATHWAYS MODEL																					
1020 CHARACTERIZE ECOSYSTEM EFFECTS																					
1030 EVALUATE UNCERTAINTY																					
1040 SUMMARIZE INFORMATION																					
INTERNAL DRAFT REPORT																					
DRAFT FINAL REPORT																					
FINAL REPORT																					

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

881 HILLSIDE
ENVIRONMENTAL EVALUATION
ACTIVITY SCHEDULE

FIGURE 6-7 JULY 1991

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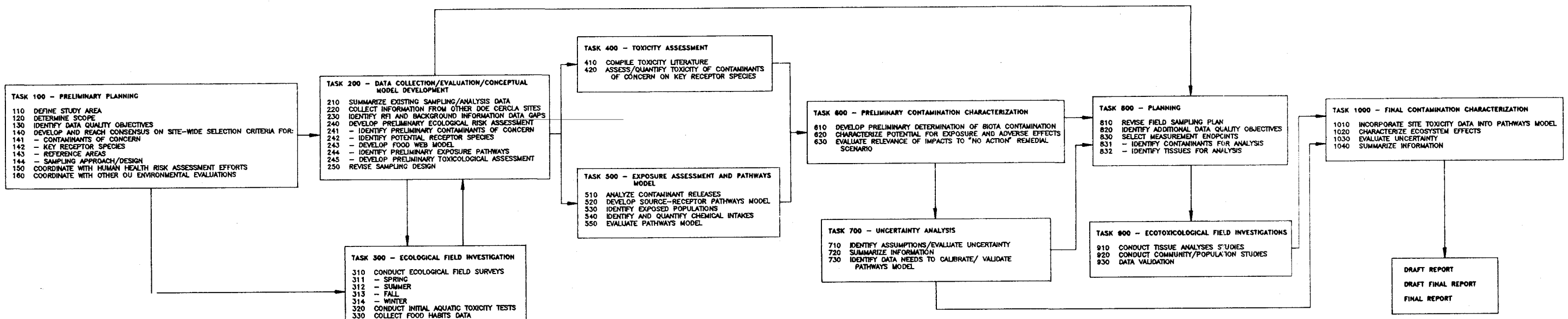

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OPERABLE UNIT 1
PHASE III RFI/RI WORK PLAN

FLOW DIAGRAM:
INTERRELATIONSHIPS BETWEEN TASKS

FIGURE 6–1 MAY 1991

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